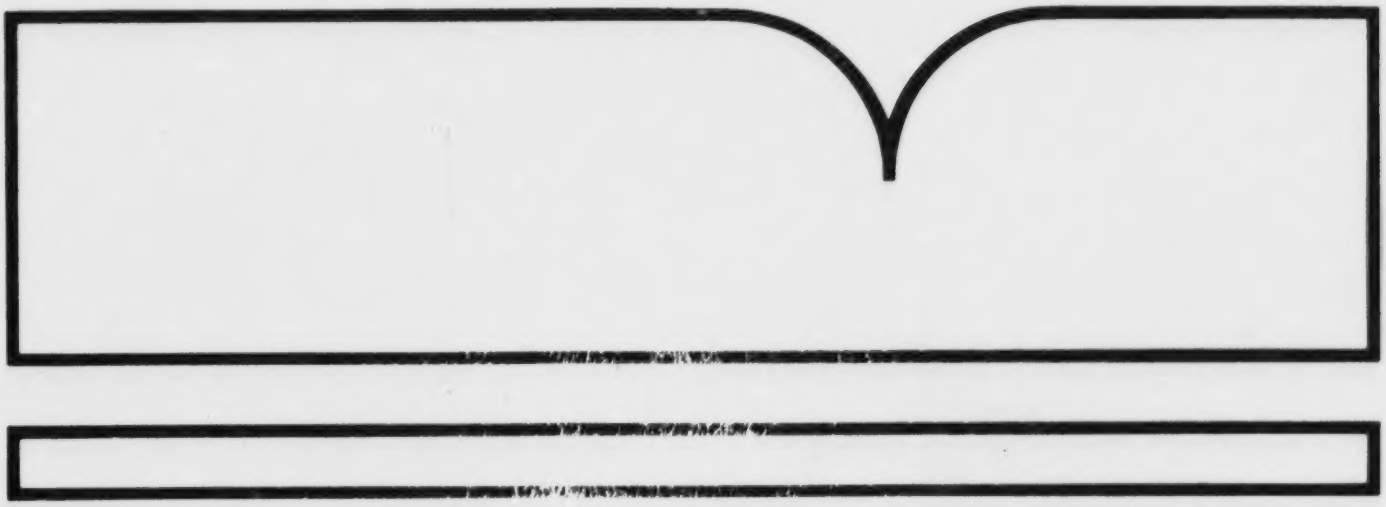
PB82-239401

Estimated Exposure to Ambient Carbon Monoxide Concentrations under Alternative Air Quality Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Aug 80



U.S. Department of Commerce
National Technical Information Service
NTIS

PB82-239401

DRAFT

Estimated Exposure to Ambient Carbon Monoxide Concentrations Under Alternative Air Quality Standards

Strategies and Air Standards Division
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

August 1980

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

V 204037

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO. PB82-239401
4. TITLE AND SUBTITLE ESTIMATED EXPOSURE TO AMBIENT CARBON MONOXIDE CONCENTRATIONS UNDER ALTERNATIVE AIR QUALITY STANDARDS		5. REPORT DATE August 1980 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) William F. Biller: East Brunswick, NJ Thomas B. Feagans, George M. Duggan: US EPA Ted R. Johnson, James E. Capel: PEDCo Environmental, Inc.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Strategies and Air Standards Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

An important element in considering possible alternative air quality standards is the (uncertain) population exposure to pollutant concentrations that would result if a given standard were just attained. As part of the current review of the National Ambient Air Quality Standards for carbon monoxide (CO), estimates have been made of exposures of the populations of nine U.S. cities to selected CO levels under existing conditions and assuming attainment of various alternative standards. These estimates have been made for both hourly and daily interpretaions of statistical standards stated in terms of expected annual exceedance rates of a given concentration level. Selected estimates are tabulated in section 4.0. The estimates are also extrapolated to the Urban U.S. population. Two models have been developed for extimating exposures to ambient carbon monoxide levels. The first model estimates average person-hours of exposures per year to one-hour average concentrations of CO at or above given conecntration levels. The second model estimates average number of exposures to eight-hour average concentrations of CO at or above given levels. The models attempt to take into account the behavior of both people and ambient levels of carbon monoxide. Sparsity of information on several of the needed inputs and the first generation nature of the models make the accuracy of the estimates uncertain. Tables and print-outs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Quality Standards Carbon Monoxide Air Pollution Air Pollution - Models		EPA 68A

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 86
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

Estimated Exposure to Ambient Carbon Monoxide Concentrations Under Alternative Air Quality Standards

William F. Biller
East Brunswick, New Jersey
Thomas B. Feagans
U.S. Environmental Protection Agency
Ted R. Johnson
PEDCo Environmental, Incorporated
George M. Duggan
U.S. Environmental Protection Agency
James E. Capel
PEDCo Environmental, Incorporated

Strategies and Air Standards Division
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

Acknowledgements

Discussions with Dr. Wayne Ott and Dr. Dave Mage of EPA's Office of Research and Development have contributed significantly to the development of the two models described in this report. The work done by Marc Roddin, Hazel Ellis, Waheed Siddiqee, and Robert Lieberman of SRI International on human activity pattern data (see referenced reports) was instrumental to the timely application of these models. Managerial and substantive assistance was provided by Thomas McCurdy of EPA, Carl Nelson of PEDCo Environmental, Inc., and Joel Norman of SRI International. Irene Griffin of PEDCo Environmental, Inc. assisted in data collection and data reduction.

1.0 Introduction

An important element in considering possible alternative air quality standards is the (uncertain) population exposure to pollutant concentrations that would result if a given standard were just attained. As part of the current review of the National Ambient Air Quality Standards for carbon monoxide (CO), estimates have been made of exposures of the populations of nine U.S. cities to selected CO levels under existing conditions and assuming attainment of various alternative standards. These estimates have been made for both hourly and daily interpretations of statistical standards stated in terms of expected annual exceedance rates of a given concentration level. Selected estimates are tabulated in section 4.0. The estimates are also extrapolated to the Urban U.S. population.

Making use of some ideas that have been developed by other investigators (see discussion in [1]), two models have been developed for estimating exposures to ambient carbon monoxide levels. The first model estimates average person-hours of exposures per year to one-hour average concentrations of CO at or above given concentration levels. The second model estimates average number of exposures to eight-hour average concentrations of CO at or above given levels. The two models are described in section 3.0.

The models attempt to take into account the behavior of both people and ambient levels of carbon monoxide. Sparsity of information on several of the needed inputs and the first generation nature of the models make the accuracy of the estimates uncertain. In a more complete analysis than that reported here the models would be probabilistic, so that uncertainties in the major variables

would be represented probabilistically. The resulting outputs would be probabilistic; these outputs would represent the uncertainty about the average number of exposures in each case. In the present study, bounds were estimated for the quantities whose uncertainty had the largest impact on the exposure estimates, and lower bound and upper bound estimates are calculated on this basis alone. In order that this and other limitations of the models presented in section 3.0 can be better understood, section 2.0 describes briefly the complexities that must be dealt with in estimating exposures; an indication is given of how more refined models, currently under development, will improve on the models described in section 3.0.

Appendix A presents technical details about the two models described in more general terms in section 3.0. Appendix B describes in more detail than is given in section 3.0 how pollutant concentrations at monitoring sites were estimated. Appendix C explains how the particular matrices were constructed that are used in the current analysis to derive estimated CO concentrations in five types of environmental settings from CO concentrations at monitoring sites. Appendix D documents the computer program used to calculate the exposure estimates.

2.0 Estimating Future Exposures to NAAQS Pollutants

2.1 Complexities in Estimating Exposure

Estimation of future exposures to NAAQS pollutants if various possible air quality standards were just met is not a simple task. The following list enumerates some of the complexities and problems that must be dealt with in general:

1. Within a given geographical area pollutant concentrations vary over space at a given instant in time (this is particularly true of CO; see [2]).

2. A determination of compliance or non-compliance with standards is determined on the basis of data from a network of fixed monitoring stations.
3. Pollutant concentrations at a given monitoring site vary stochastically over time, even if there are no general trends in emissions or meteorological variables.
4. There generally are trends in at least pollutant emissions.
5. There are a limited number of years of pollutant concentration data available for most urban areas.
6. There are missing data in the years for which data are available.
7. Frequently there is measurement error in the available pollutant concentration data.
8. The time pattern of pollutant concentrations at a given monitoring site would not be the same were a given standard just met as it is for situations under which available data were collected.
9. The time pattern of pollutant concentrations at various places including monitoring sites, would not be the same for all emission mixes which just achieve a given standard.
10. People move around in space over time in ways that are not totally predictable, and to the extent that such movements follow predictable patterns these patterns are a function of several variables.
11. The currently available data on how people move around were not collected for the purpose of estimating exposure to air pollution [1].

The approach taken at this early stage in dealing with these and other complexities should, to the extent feasible, be an approach which can be built on in the future as relevant information grows and exposure models become more

refined. The basic approach taken in this analysis incorporates some of the ideas developed by Dr. Wayne Ott, et.al. [3], who will be among those generating relevant information in the future. The approach is designed to be easily refined in the direction this research is going, to incorporate new relevant information easily, and to deal with the constraints inherent in doing exposure analyses in support of NAAQS's.

2.2 Some Salient Aspects of the Basic Approach

The following is an enumeration of some of the salient features of the basic approach:

(1) the day is divided into k time intervals of equal length;

(2) the study area (city) is divided into m subareas;

(3) each subarea is divided into (the same) n types of environmental settings (which exhaust the possibilities);

(4) for each time interval of the day the population of the study area is apportioned by age/occupation category among the m subareas;

(5) for each time interval of the day the subpopulation apportioned to the m_ith subarea is subapportioned to the n environmental settings and is assigned one of j exercise levels;

(6) the finite and fixed monitoring network provides the set of base values from which the pollutant concentration in each environmental setting is estimated by transformation of the base values;

(7) Since the peak values at the monitoring network determine compliance, alternative sets of base values are associated with alternative standards.

There are many other aspects of any particular application of this approach which result from the specification of a particular model, such as the two specified in section 3.0. However, the above list should indicate the nature of the solution to the following problem: In general a finite and fixed monitoring network cannot capture inherent spatial variation in pollutant concentrations, yet a finite and fixed monitoring network is the most practical means of implementing air quality management programs. The solution to this problem is to determine compliance based on what happens at the finite number of monitoring sites, through research learn as much as feasible about how values in particular kinds of environmental settings relate to values at monitoring sites, and then incorporate this information into exposure assessments done for the expressed purpose of informing NAAQS decisions. NAAQS decisions are then based on estimates of actual exposures. (Note, however, that in the present analysis the contributions of indoor sources of CO are not included.)

2.3 Future Improvements

Future improvements can be classified into two broad categories; refinements in the exposure models and, conjointly, improvements in data. The future refinements in the exposure models can be further subclassified; there are refinements which better model the situation being modeled and refinements which represent more of the existing uncertainties probabilistically.

Doing sensitivity analyses on significant uncertainties is better than treating them as certainties, but ideally they would be represented probabilistically. Point estimates of future numbers of exposures or average numbers of exposures above certain levels would be acceptable if statistical confidence

intervals could accompany such point estimates. But it will be a long time, if ever, before the overall state of information will be sufficient to support statistical confidence intervals on the outputs of NAAQS exposure assessments. Rather, the outputs will most suitably be in probabilistic form. The models used to generate these probabilistic outputs will most likely be simulation models which use probabilistic representations of uncertainties as inputs.

Only the pollutant concentration aspects of the two models described in section 3.0 are handled probabilistically; the models are not designed to give probabilistic outputs. Failure to represent insignificant uncertainties probabilistically is not an important limitation, but some of the uncertain quantities simply estimated in calculating the estimates presented in section 4.0 could be significant. Future sensitivity analyses will make clear which of these uncertainties have the greatest impact on the exposure estimates. The approach taken in this report of making upper and lower bound estimates of population exposures by using upper and lower bound estimates for the most important uncertain quantities is a temporary expedient made necessary by time limitations.

There are many possible improvements in the modelling of exposure situations. The day can be divided into finer time segments than the 24 one hour intervals used for the present analysis; in the ongoing research mentioned above the day is divided into 96 fifteen minute intervals [3]. The exhaustive set of environmental settings can be refined; a refined set has been developed in the aforementioned research.

Because there are limits to the number of environmental settings it is practical to use, it would be desirable to have distribution elements rather than a single linear factor in the matrix used to transform the base pollutant

concentrations into concentration estimates for the environmental settings. Information on how pollutant concentrations and people distribute through time within the environmental settings could then be improved. Refinements such as this could be made for the environmental settings in which the highest concentrations occur without doing it for the other environmental settings.

Other possible improvements include generating base concentration values through spatial interpolation schemes [4] and time series modelling [5], [6]; developing more satisfactory means of adjusting pollutant concentration regimes from the assumption that one standard is being met to the assumption that another standard is being met [7]; and making better assignments of subpopulations to particular base concentrations over time by using population centroids [8] and using transportation data on the movement of people among the various districts of the study area.

As is indicated in Appendix C, there is a great need for more information from which the factors used to transform monitor site concentrations to concentrations in the various environmental settings can be derived. This type of information will be increasing and improving through various types of research. In the case of pollutants, such as CO, for which personal dosimeter technology is available research with personal dosimeters will make a large contribution. Both point source and line source dispersion modelling can contribute [9].

It is common practice when introducing new models to discuss plans for calibrating and/or validating the models [10]. In this instance such a discussion would lead into a series of complex topics that are beyond the scope of this report. Suffice it to say here that some future research will

address the analagous questions that apply to models that most appropriately have probabilistic outputs and that the nature of these analagous questions will be discussed in other EPA reports [11].

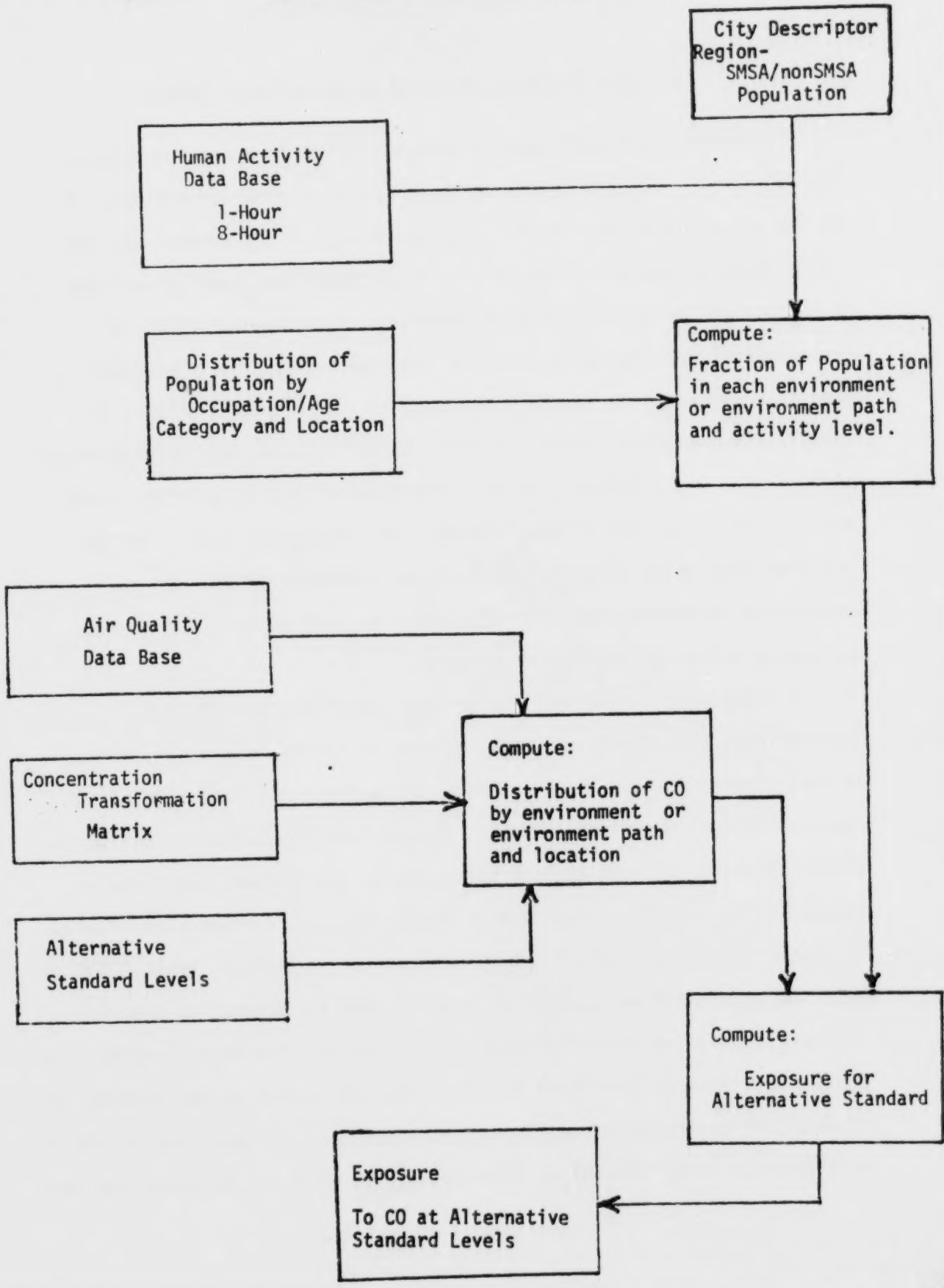
Various output measures other than those calculated in the analysis reported on here can be developed. Of particular interest for setting a NAAQS would be exposures of population groups most sensitive to the adverse health effects contributed to by the given pollutant. The uncertainty about these exposures and their resultant health effects are both elements in important health risks associated with alternative ambient air quality standards. Therefore, outputs of risk models that incorporate both of these uncertainties are of major interest [11]. The Agency is currently supporting a program in which such models are being developed.

3.0 Description of Carbon Monoxide Exposure Models

The one-hour and eight-hour CO exposure models have the same general form (Figure 1). In both models it is necessary to know for each hour of the day where people are and what they are doing. It is assumed that the large number of possible situations in which people are found at any time of the day can be approximately represented by a reasonable number of environmental settings and activity or exercise levels. In the present case five environmental settings have been assumed: indoors at work or school, other indoors, inside a transportation vehicle, other transportation along a road, and outdoors. In each environmental setting exercise levels are classified into one of three ranges: low, medium and high. The low level corresponds to lying down, sitting or standing; medium activity corresponds to walking and other mild exercise; high activity corresponds to running and other heavy exercising.

In developing the models, studies were undertaken for EPA by SRI International [12] to estimate for each hour of the day how the population is distributed among the five environmental settings and three possible exercise levels within each setting. To take into account variations in the distribution due to location, the United States was divided into three climatological regions. Areas within the regions were further classified as to whether they fell within Standard Metropolitan Statistical Areas (SMSA) or not. The population was classified into thirteen age/occupation categories. The week was divided into three categories: weekday (Mon-Fri), Saturday, and Sunday, and the year into three periods. The information on the distribution of people by environmental setting and exercise level for each hour of the day as a function of age/occupation category, day of the week, period of the year,

Figure 1 CARBON MONOXIDE EXPOSURE MODEL



SMSA/nonSMSA and region of the U.S. constitutes a human activity data base. In the one-hour model the data base is combined with CO ambient concentration data to estimate exposures.

The data base on human acitivities has to be taken another step to be used in the eight-hour model. In this case it is necessary to take into account the various environmental settings to which an individual has been exposed over any consecutive eight hours. As discussed above, it is assumed in any hour an individual is predominately in one of five representative environmental settings. Therefore, a listing of the environmental settings occupied over a twenty-four hour period defines a daily environmental path for an individual. The eight-hour model assumes that for each age/occupation category there are three representative daily paths. The specification of the daily path age/occupation subgroup and the percentage of the corresponding age/occupation group in each subgroup are assumed to vary with Region, SMSA/nonSMSA designation, type of day, and period of the year. The study mentioned above was extended to specify the path and the distribution of the age/occupation groups among their three subgroups. Because of time constraints the number of age/occupation groups considered was limited to ten, and effects of region and time of year were not taken into account.

Given the above mentioned data base of daily paths, the subpaths for any eight-hour period and the distribution of a given population over these subpaths can be determined.

Given the distribution of a population by environmental setting for each hour of the day or by environmental path for each of the twenty-four possible consecutive eight-hour periods that can be associated with a day, it is next necessary to account for the CO levels that will be experienced each hour by individuals in the environmental settings or environmental paths. A given area, depending on its size, may have from one to several sites at which the

air quality is monitored. The area surrounding each site is considered to be made up of the five environmental settings. A portion of the total population is assigned to each site. In the present calculation the population is divided evenly among the sites and population per site is considered constant over the day. These assumptions were made necessary by time constraints and lack of data and will be modified in future refinements of the calculations.

It is well established that CO concentrations vary widely with location at a given time of day. As a result the concentrations experienced within any of the five environmental settings associated with a given site can vary markedly from that indicated at the monitor site. Presently there is insufficient information to accurately treat these differences and this deficiency is considered to be the major source of error in the calculation. It is assumed that the average concentration for any hour in a given environment is proportional to the concentration at its associated monitor site. This assumption is an oversimplification and will be modified in future work. Because of the large uncertainties in estimating the relationships between the monitoring sites and their associated environments, upper and lower bound values were estimated for the proportionality constants connecting monitoring sites and environmental settings.

The models assume that if emission control programs affect a change in emissions to comply with a given standard, the ambient concentrations of CO will be changed by the same factor at all sites, with due allowance for background levels. That is, proportional rollback of CO levels is assumed at each monitoring site. The degree of rollback required can be calculated based on either an hourly or daily interpretation of a statistical standard based on an allowed expected exceedance rate.

Distribution functions were fit to annual one-hour average CO concentration data sets for each monitor site for the area under study. Because lognormal

distributions gave reasonably good fits, they were used in all the calculations. These distributions were used primarily to calculate the parameters of the annual distribution of one-hour average CO concentrations for each monitoring site when a given standard level was just being met at the most critical monitoring site for the area. However, because the distribution of the population among the five environmental settings associated with each site changes with each hour of the day, it was necessary to develop separate distributions for each hour of the day for each monitoring site. It was found that these distributions could also be reasonably well represented by lognormal distribution functions. However, some adjustments were required to bring the individual hour distributions into agreement with the overall distribution. Given the individual hour distributions for each site and the above assumptions regarding the associated environmental settings, the parameters of the distribution functions corresponding to each environmental setting were then estimated. From these distributions the average fraction of one-hour CO concentrations above a given concentration could be calculated at each environmental setting when a given standard was just met at the critical site for the area. These data were then combined with the data on the distribution of people by environmental setting for each hour of the day to calculate the total exposure per year to one-hour concentrations at or above a given level.

To make full use of the data developed on the distribution of people among the five environmental settings, separate CO ambient concentration distributions should be obtained for each of the three types of days and seasons of year. Data limitations made inclusion of this procedure impractical in the present calculation.

Calculation of exposure to eight-hour average concentrations above a given level is more complicated than for the one-hour exposures because it is

necessary to account for the movement of people through the various environmental settings over all possible eight-hour periods in a year. Thus, it is not sufficient to repeat the above calculation for one-hour CO exposures using distributions of eight-hour average CO concentrations. Appendix A shows how approximate parameters for distribution by path rather than by environment may be derived from one-hour and eight-hour average exposures in a year at or above a given concentration level for each environmental path associated with a given level at a given standard level.

The models were applied to data from Los Angeles, Phoenix, San Jose, Washington, D.C., Philadelphia, Tampa, Steubenville, Ohio, St. Cloud, Minnesota, and Rock Hill, North Carolina. The last mentioned area was the only rural area included in the study. Exposure estimates for urban areas of the United States were made by partitioning the urban areas studied into their respective climatological regions and summing the exposures within each region. These exposures were then scaled up to correspond to the total population within each region and added together to give total U.S. exposure.

4.0 Results

Selected results are presented in three tables. Table 1 presents 1-hour average lower and upper bound expected exposure estimates. Table 1(a) presents the estimates made for the urban population of the United States; here considered to be the 140,000,000 people who live in Standard Metropolitan Statistical Areas (SMSA's). Table 1(b) presents the estimates made for a sample one of the nine SMSA's used to make the extrapolation to the whole U.S.; namely, Washington, D.C. The estimates are of expected person-hours of exposure per year greater than or equal to three concentrations: 50 ppm, 35 ppm, and 25 ppm. The estimates are made for eight possible standards and the current situation.

To specify a standard the following must be specified: an averaging time; a standard level; the number of expected exceedances of the standard level allowed per year; and whether this expected number of exceedances is to be given an hourly or a daily interpretation. The eight standards are obtained by combining four possible standard levels with either an hourly or daily interpretation; a 1-hour averaging time and one expected exceedance of the standard level are common to all eight standards considered.

Consider, as an example, the question of how many person-hours of 1-hour average CO exposures above 25 ppm would occur in urban areas during an upcoming year if the following standard were just attained: standard level = 0.35 ppm; 1-hour averaging time, one expected exceedance, and daily interpretation. The lower bound estimate given in Table 1 is 76,400,000 expected person-hours of exposure, and the upper bound estimate is 1,100,000,000 person-hours of exposure.

The estimates are given in terms of lower and upper bounds for reasons explained in the earlier sections of this document. The lower bound estimate of 76,400,000 expected person-hours means that the average number of person-hours of exposure over a long number of years is estimated to be greater than 76,400,000; the upper bound estimate of 1,100,000,000 expected person-hours means that the average number of person-hours of exposure over a long number of years is estimated to be less than 1,100,000,000.

Two points should be noted. First, the fact that the average number of person-hours of exposure over a long number of years is estimated to be between 76,400,000 and 1,100,000,000 does not mean that it is estimated that in any given year the number of person-hours of exposure would be between 76,400,000 and 1,100,000,000. Second, it is not certain that the average number of person-hours of exposure over a long number of years would be between 76,400,000 and 1,100,000,000.

Table 2 presents 8-hour exposure estimates. It is similar in form to Table 1. Table 2(a) presents estimates for the urban U.S. and Table 2(b) presents estimates for Washington, D.C. The three exposure levels used are 15 ppm, 12 ppm, and 9 ppm. The four standard levels are 15 ppm, 12 ppm, 9 ppm, and 7 ppm.

Table 3 presents a breakdown of some sample total expected exposure estimates for the urban U.S. into estimates for each of the three exercise levels: low, medium, and high. Table 3(a) gives an 1-hour average case and table 3(b) an 8-hour average case for the urban U.S. These estimates illustrate a point which holds in general: the number of exposures at the low exercise level are estimated to be much higher than those at the medium and high exercise levels.

Table 1. Expected Person-Hours of Exposure Per Year to 1-Hr Average CO Concentrations

(a) Urban United States (Population = 140,000,000)

Standard Level; Interpretation (1 Expected Exceedance)	≥ 50 ppm		≥ 35 ppm		≥ 25 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
40 ppm; Daily	5,580,000	105,000,000	30,300,000	498,000,000	138,000,000	1,880,000,000
40 ppm; Hourly	4,290,000	82,600,000	23,600,000	398,000,000	109,000,000	1,530,000,000
35 ppm; Daily	2,890,000	57,100,000	16,200,000	283,000,000	76,400,000	1,100,000,000
35 ppm; Hourly	2,220,000	44,400,000	12,600,000	225,000,000	60,000,000	913,000,000
Current Situation	1,590,000	38,000,000	9,390,000	187,000,000	45,800,000	756,000,000
25 ppm; Daily	526,000	11,400,000	3,190,000	62,800,000	16,200,000	283,000,000
25 ppm; Hourly	400,000	8,800,000	2,460,000	49,000,000	12,600,000	225,000,000
20 ppm; Daily	164,000	3,780,000	1,040,000	21,800,000	5,560,000	106,000,000
20 ppm; Hourly	124,000	2,900,000	797,000	16,900,000	4,300,000	83,100,000

Table 1. Expected Person-Hours of Exposure Per Year to 1-Hr Average CO Concentrations

(b) Washington, D.C. (Population = 3,061,000)

Standard Level; Interpretation (1 Expected Exceedance)	≥ 50 ppm		≥ 35 ppm		≥ 25 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
40 ppm; Daily	62,900	1,550,000	327,000	7,240,000	1,570,000	28,300,000
40 ppm; Hourly	49,300	1,220,000	255,000	5,780,000	1,230,000	22,900,000
35 ppm; Daily	34,600	851,000	175,000	4,110,000	847,000	16,700,000
35 ppm; Hourly	27,400	668,000	137,000	3,270,000	660,000	13,500,000
Current Situation	19,200	460,000	94,000	2,290,000	450,000	9,640,000
25 ppm; Daily	8,300	182,000	37,900	937,000	176,000	4,130,000
25 ppm; Hourly	6,690	142,000	30,100	737,000	138,000	3,290,000
20 ppm; Daily	3,410	64,100	14,500	339,000	63,200	1,560,000
20 ppm; Hourly	2,780	50,300	11,600	266,000	49,900	1,240,000

Table 2. Expected Number of 8-Hr Average CO Exposures

(a) Urban United States (Population = 140,000,000)

Standard Level; Interpretation (1 Expected Exceedance)	≥ 15 ppm		≥ 12 ppm		≥ 9 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
Current Situation	255,000,000	5,530,000,000	752,000,000	13,700,000,000	3,180,000,000	36,800,000,000
15 ppm; Daily	52,300,000	708,000,000	135,000,000	2,210,000,000	462,000,000	9,260,000,000
15 ppm; Hourly	26,600,000	333,000,000	69,300,000	1,010,000,000	235,000,000	4,390,000,000
12 ppm; Daily	19,700,000	243,000,000	51,800,000	717,000,000	176,000,000	3,150,000,000
12 ppm; Hourly	9,930,000	121,000,000	26,600,000	341,000,000	91,500,000	1,450,000,000
9 ppm; Daily	5,350,000	65,900,000	14,600,000	181,000,000	51,000,000	736,000,000
9 ppm; Hourly	2,690,000	34,000,000	7,440,000	92,000,000	26,700,000	355,000,000
7 ppm; Daily	1,640,000	21,300,000	4,600,000	57,600,000	16,800,000	216,000,000
7 ppm; Hourly	830,000	11,200,000	2,360,000	30,300,000	8,780,000	111,000,000

Table 2. Expected Number of 8-Hr Average CO Exposures
(b) Washington, D. C. (Population = 3,061,000)

Standard Level; Interpretation (1 Expected Exceedance)	≥ 15 ppm		≥ 12 ppm		≥ 9 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
Current Situation	1,670,000	30,300,000	4,270,000	85,700,000	16,800,000	323,000,000
15 ppm; Daily	277,000	4,410,000	656,000	11,000,000	2,070,000	39,500,000
15 ppm; Hourly	152,000	2,420,000	361,000	5,830,000	1,110,000	19,800,000
12 ppm; Daily	117,000	1,860,000	277,000	4,440,000	848,000	14,700,000
12 ppm; Hourly	64,500	1,050,000	154,000	2,460,000	470,000	7,790,000
9 ppm; Daily	37,600	622,000	90,700	1,460,000	278,000	4,500,000
9 ppm; Hourly	20,900	354,000	50,800	833,000	157,000	2,530,000
7 ppm; Daily	13,600	236,000	33,500	557,000	105,000	1,690,000
7 ppm; Hourly	7,610	136,000	19,000	323,000	59,900	980,000

Table 3. Breakdown of Total Expected Exposure for Urban U.S. by Exercise Level

(a) 1-Hr Average CO Exposures Associated with a Standard Level of 25 ppm (1 Expected Exceedance, Dialy Interpretation)

Exercise Level	≥ 50 ppm		≥ 35 ppm		≥ 25 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
Low	519,000	11,300,000	3,150,000	62,000,000	16,000,000	279,000,000
Medium	6,230	116,000	40,800	701,000	223,000	3,630,000
High	411	12,200	2,860	75,100	17,200	400,000
Total	526,000	11,400,000	3,190,000	62,700,000	16,200,000	283,000,000

(b) 8-Hr Average CO Exposures Associated with a Standard Level of 9 ppm (1 Expected Exceedance, Daily Interpretation)

Exercise Level	≥ 15 ppm		≥ 12 ppm		≥ 9 ppm	
	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate	Lower Bound Estimate	Upper Bound Estimate
Low	4,780,000	57,500,000	12,900,000	159,000,000	45,100,000	665,000,000
Medium	412,000	6,100,000	1,210,000	16,100,000	4,530,000	54,900,000
High	151,000	2,230,000	410,000	5,300,000	1,390,000	15,700,000
Total	5,350,000	65,900,000	14,500,000	181,000,000	51,000,000	736,000,000

APPENDIX A

BASIS FOR EXPOSURE MODELS

One-Hour Model

The following assumptions provide the basis for the 1-Hour Carbon Monoxide Exposure Model.

1. The numerous activities people are found in at any time may be adequately represented as taking place in a finite and relatively small (e.g., < 50) number of environments.
2. The continuum of activity or exercise levels people are engaged in at any time can be adequately represented by a finite and relatively small number of levels.
3. Each of the ambient air monitoring sites in an area for which exposure estimates are to be made accounts for the air quality of the area surrounding the site. These sub-areas account for all the land and population encompassed by the area. Each sub-area will contain all the environments referred to in #1. These environments are not necessarily associated with specific locations within the sub-area.
4. During each of the 24 one-hour periods of the day: 12 AM to 1 AM, 1 AM to 2 AM ····· 11 PM to 12 AM, any member of the population is predominately in one monitoring site/environment at one exercise level.

5. All individuals within a monitoring site/environment during a given hour are exposed to the same ambient levels of carbon monoxide (CO).

6. The population of an area may be divided into a relatively small number of age/occupation groups.

7. The distribution of any age/occupation group among the monitoring sites is a function of: the area, the placement of the monitoring sites, age/occupation group, period of the year, type of day (e.g., weekday, Saturday or Sunday), and hour of the day.

8. The distribution of any age/occupation group among the environments associated with a given monitoring site is a function of climatological region of the USA, whether the area is urban or non-urban (i.e., whether the area is a Standard Metropolitan Statistical Area (SMSA) or not), period of the year, type of day, and hour of the day.

9. The variation in measured 1-hour average CO concentrations at a given site can be adequately represented by a 2 parameter distribution function. Furthermore, 2-parmeter distribution functions of the same functional form can be determined for each of the 24 one-hour periods described in #4, partitioned by type of day and period of the year.

10. After background is taken into account there is a proportional relationship between emissions of CO and ambient levels of CO. The constant of proportionality is the same for all sites in the area.

11. CO levels in a given environment are directly proportional to the CO level at the associated monitoring site after taking background into account. The constant of proportionality is a function of the site and the location of its associated environment.

Let $G(C,\mu,\sigma)$ represent the distribution of 1-hour CO concentrations. G is the fraction of 1-hour average concentrations occuring over an extended period of time which are greater than or equal to C. μ and σ are a scale parameter and shape parameter, respectively. Then by Assumption #9 $G(C, \mu_j, \sigma_j)$ is the distribution for concentrations occuring in the jth hour of the day. The expected total person hours of exposure to 1-hour average concentrations greater than or equal to C in a one year period in a given geographic area just meeting a standard C_{STD} is given by:

$$E(C,C_{STD}) = P \sum_h \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n W_h D_i A_{h,i,j,k,l,m,n} \cdot G(C,\mu_{h,i,j,l,m}(C_{STD}), \sigma_{h,i,j,l}) \quad (1)$$

Where the indicies are:

- h = Time of year (season)
- i = Type of day (weekday, Saturday, Sunday)
- j = Hour of day
- k = Age/occupation group
- l = Monitoring site
- m = Environment
- n = Exercise level

A = Fraction of the population in environment m, at exercise level n, in the vicinity of site l, in age/occupation group k, during the jth hour of the day, in a day of type i and an annual time period of type k.

D_i = Number of days of type i in a week.

W_h = Number of weeks in an annual time period of type h.

P = Total population of the area.

The factors A, D, and W have the following properties:

$$\sum_k \sum_l \sum_m \sum_n A_{h,i,j,k,l,m,n} = 1 \text{ (for any h,i,j)} \tag{2}$$

$$\sum_i D_i = 7 \tag{3}$$

$$\sum_h W_h = 52.14 \text{ (assuming a 365 day year)} \tag{4}$$

The functions $G(C,\mu,\sigma)$ have the property:

$$\int_0^\infty G(C,\mu,\sigma)dC = 1 \tag{5}$$

The day types chosen for the CO exposure analysis are weekdays, Saturday and Sunday and therefore D_i takes the values 5, 1, 1. The year is divided into three periods of equal length and, therefore, $W_h = 17.38$ for h = 1,2,3.

In determining the μ and σ parameters for a particular standard the starting point is the set of μ and σ parameters for the CO concentrations observed at the monitoring sites. As discussed more fully in Appendix B, a suitable functional form is chosen for the monitoring site data by fitting various forms to data sets for each site in an area. A single form is chosen for the area. In the present case 10 areas were studied and the lognormal functional used for each.

It is assumed that the form of the ambient air standard is:

> C_{STD} ppm with an expected exceedance rate not greater than once per year.

This standard may have an hourly or daily interpretation. In the hourly interpretation the concentration level C_{STD} refers to the 8760 one-hour average concentrations in a 365 day year at a monitoring site. In the daily interpretation C_{STD} refers to the 365 daily maximum concentrations at a monitoring site.

From the statistics of extreme values the concentration which has an expected exceedance rate of one would be defined as the characteristic highest value of the distribution of concentrations. For a year of 8760 hourly average concentrations it is the value of C for which $G(C,\mu,\sigma) = 1/8760$. For the daily maximum concentrations it is the value of C for whcich $G_d(C,\mu,\sigma) = 1/365$ (where G_d is the distribution of daily maximum one-hour concentrations). An alternative way to state the above form of the standard is that the annual characteristic highest concentration should not exceed C_{STD}.

The characteristic highest value can be obtained from the parameters of the fitted distribution function. The relationship for the lognormal distribution is as follows:

The lognormal distribution is:

$$G(C,\mu,\sigma) = \int_{C}^{\infty} \frac{1}{\sqrt{2\pi}\sigma C} \exp\left(\frac{(\log C - \mu)^2}{2\sigma^2}\right) dC$$

If we put the distribution into its standard form by the following transformation:

$$z = \frac{\log C - \mu}{\sigma}$$

Then:

$$G(C,\mu,\sigma) = \int_{z}^{\infty} \frac{1}{\sqrt{2\pi}\sigma} \exp\left(z^2/2\right) dz$$

The normal integral on the right has been tabulated and appears in most texts dealing with statistics [13]. If the characteristic highest concentration is designated by C1, at C = C1, by definition G = 1/8760.

The tabulation of the normal form indicates that value of $\hat{z}$ which yields this value of G is 3.686. We, therefore, have from the definition of $\hat{z}$:

$$\frac{\log Cl - \mu}{\sigma} = 3.686$$

or:

$$Cl = \exp(\mu + 3.686\,\sigma) \tag{6}$$

It should be noted that the characteristic highest value is in general not equal to the expected highest value. The quantity Cl can always be determined directly from the distribution of concentrations whereas in general the expected highest value must be obtained from the distribution function of the highest values. The latter distributions is not usually directly derivalbe from the distribution of concentrations owing to correlation and nonstationarity effects which are normally present with ambient air pollutant concentrations [6].

To determine whether an area complies with a standard of the form given above, the characteristic highest concentration is determined for each monitoring site within the area. The highest Cl for the area must be at the standard or below for compliance. If it is above, the highest Cl is used as the design value for determing the degree to which emissions within the area must be reduced in order to achieve compliance. This approach was followed in the exposure model.

The monitor with the highest value of Cl will be called the critical site. Taking background CO concentrations into account, the fractional reduction in emissions required to meet the standard at the critical site is by Assumption #10:

$$r = \frac{Cl \text{ (critical site)} - C_{STD}}{Cl \text{ (critical site)} - C_{BKD}} \tag{7}$$

Equation (7) applies to an hourly interpretation of the standard. If a daily interpretation is used then the standard level C_{STD} has to be adjusted slightly by multiplying by a factor of 0.948. This factor was determined by comparing calculated characteristic highest values for both hourly and daily maximum concentrations obtained from the same data sets. It is the average proportionality factor between the two characteristic high concentrations.

Under Assumption #10 the factor to be applied at each site to maintain proportionality is:

$$f_{Site} = \frac{(Cl_{Site} - C_{BKD})(1-r) + C_{BKD}}{Cl_{Site}} \tag{8}$$

To make a proportional reduction in all concentrations observed at a site the factor f_{Site} is only applied to the scale factor μ (in the lognormal distribution this is μ, the mean value of log C).

Assumption #11 leads to another set of factors which take into account the proportionality between a monitoring site and an associated environment. These factors can be a function of site, environment, time of year, type of day, and hour of day and are designated by γ.

By fitting distributions of the form G to subsets of the monitoring data, the μ and σ values at each site can be obtained for individual hours of the day, day type, and period of the year. It is to the μ-values of these sets of parameters that the f_{site} and γ factors are applied. In the case of the lognormal distribution it can be shown the $\mu_{h,i,j,l,m}(C_{STD})$ appearing in Eq. (1) is given by:

$$\mu_{h,i,j,l,m}(C_{STD}) = \log \gamma_{h,i,j,l,m} f_l(C_{STD}) + \mu_{h,i,j,l} \tag{9}$$

$$= \mu_{h,i,j,l} + \log (\gamma_{h,i,j,l,m} f_l(C_{STD}))$$

In the calculations discussed in this report it was assumed that there were no seasonal or day of the week effects for the γ, f, and μ. In the case of the γ factors it was also assumed there was no effect of hour of the day. It was also assumed that the population was divided evenly among the monitoring sites at all times of the day, week and year.

A more accurate but more involved method of applying γ and f would fit the distributions to the concentration data after the backgrounds have been subtracted. In this case $f_1 = (1-r)$.

Eight-Hour Model

Calculating exposure to 8-hour average concentrations is considerably more complex than calculating 1-hour exposures because it becomes necessary to take into account where people have been over any eight hour period. To do the 8-hour case properly probably requires a simulation employing time series for the CO concentrations rather than distribution functions. The following very approximate method involving distributions was used for the present calculation.

The same simple set of assumptions used in the 1-hour model are carried over to the 8-hour case with the following additional assumptions:

1. The sequences of activities people are engaged in over any eight hour period can be adequately represented by a relatively small number of paths.

2. In a twenty-four hour period the distribution of people over monitoring sites remains constant.

3. The distribution of hourly average concentrations of CO can be represented by a simple time series displaying a diurnal variation in the scale factor which may be different for different day types and times of the year.

It is assumed the distribution of hourly concentrations can be represented by a simple time series such as:

$$\log C(t) = \mu(t) + a(t) \tag{10}$$

where $t = 1,2,3 \cdots\cdots$ and represents successive hours. The term $\mu(t)$ is assumed to show a persistent diurnal pattern. That is,

$$\mu(t) = \mu(t + 24) \tag{11}$$

$a(t)$ is a series of normally distributed values with 0 mean and standard deviation, σ.

Equation (10) can be rewritten:

$$C(t) = \exp(\mu(t) + a(t)) \tag{12}$$

or

$$C(t) = m_g(t) \exp(a(t)) \tag{13}$$

where

$$m_g = \exp(\mu(t))$$

A time series of 8-hour running averages would have the form:

$$\frac{1}{8}\Sigma C(t) = \frac{1}{8}\Sigma m_g(t)\exp(a(t))$$

$$\bar{C}(t) = \frac{1}{8}\Sigma m_g(t)\exp(a(t)) \tag{14}$$

or

$$\bar{C}(t) = \bar{m}_g\left(\Sigma_8 \frac{m_g(t)}{\bar{m}_g(t)}\exp(a(t))\right.$$

$$\log \bar{C}(t) = \log \bar{m}_g(t) + \bar{a}(t) \tag{15}$$

where:

$$m_g(t) = \frac{1}{8}\Sigma m_g(t) \tag{16}$$

$$\bar{a}(t) = \log \Sigma_8 \frac{m_g(t)}{\bar{m}_g(t)}\exp(a(t)) \tag{17}$$

Thus based on the simple model given in Eq. (10) the 8-hour running averages would approximately be represented by a lognormal distribution even with a diurnal variation in μ.

Now if the path traveled by a given fraction of the population over any eight hour period is known and it is assumed as in #2 that there is no movement between sites, the only effect of the path is to multiply the $m_g(t)$ for any hour by the factor γ corresponding to the environment on a given path for that hour. Thus, the $\bar{m}_g(t)$ for the path is:

$$\bar{m}_g(t) = \frac{1}{8} \Sigma \gamma(t) m_g(t) \tag{18}$$

APPENDIX B

DEVELOPMENT OF POLLUTANT CONCENTRATION DISTRIBUTIONS

For each monitoring site in each study area, lognormal distributions were fit to data sets collected over a one year period on 1-hour average concentrations and 8-hour running average concentrations. Fits were made using the least squares technique on a linearized form of the distribution. These yielded a mean and standard deviation (μ and σ) for the logarithm of the concentration. The 1-hour and 8-hour data sets were segregated by hour of the day and the μ's and σ's for each hour were obtained by the least squares method.

The lognormal distribution fits 1-hour CO data well but is somewhat less suited to the 8-hour data. There is further degredation in goodness of fit when fitting the data to individual hours of the day. It is likely that had the data been further segragated into type of day and season there would have been further degrading of the fit. In general the lognormal distribution tended to over predict the frequency of occurrence of the highest concentration observed over a one year period.

In applying the overall and individual hour μ's and σ's to the 1-hour model it is important that the overall and individual hour parameters be mutually consistent. A simple test is available to test for this consistency. The following situation should hold:

$$\frac{1}{24} \sum_{i=1}^{24} G(C,\mu_i,\sigma_i) = G(C,\mu,\sigma) \qquad (1)$$

Where the μ_i, and σ_i are the parameters for the individual hours of the day and the μ and σ are the overall parameters. Tests with actual data sets were made for concentrations that when substituted on the right hand side of the equation gave G values of .90, .75, .50, .1, .01, 10/8760, 2/8760, and 1/8760. Thus the overall distribution was tested over its whole range. In most cases there was reasonable agreement but not to the accuracy needed.

It was assumed that the overall parameters were more reliable than those for the individual hours. Basically what was desired in the individual hour parameters was that they reasonably reflect the diurnal nonstationarity of the CO data, and when taken as a group give results in close agreement with the overall parameters. Consequently for each site the individual hours μ's and σ's were adjusted with a multiplier to bring them into close agreement with the overall μ and σ through Eq. (1). A single multiplier was used for the μ's and a single multiplier for the σ's of a given site. Generally the needed correction was a number fairly close to 1. However, in some case initial agreement was poor and could not be improved except through large corrections. In these cases the sites were discarded. In most cities this step was not necessary. However, for St. Louis the agreement was generally poor and the city was dropped from the study.

In the 8-hour model, obtaining agreement by adjustment through Eq. (1) was somewhat less satisfactory but still practical. It was found more effective, however, to use an additive correction to the μ rather than a multiplicative correction. (In the 1-hour case, either could have been used with equal success.) The situation came about because μ may be either

positive or negative. If there are about the same number of positive and negative values in a 24 hour set, a multiplicative factor will have little effect. The geometric mean which is exp (μ) can only be positive and a multiplicative correction to it is in effect an additive correction to μ. Thus the additive correction is basically more appropriate.

The 8-hour model, uses the individual hour μ's for the 1-hour set, and the individual hour σ's from the 8-hour set. It also uses the overall 8-hour μ's and σ's. It, therefore, requires consistency between the 8-hour and 1-hour data sets. This was not obtained, largely because of an inconsistency between the procedures used in fitting the 1-hour and 8-hour sets. As a consequence the 8-hour μ's were used in the model instead of the 1-hour μ's in the present calculation. This substitution has the effect of partially meeting the diurnal nonstationarity in the CO data.

APPENDIX C

MONITOR TO ENVIRONMENTAL SETTING CO CONCENTRATION TRANSFORMATION MATRICES

As is indicated in section 4.0, an abstraction from reality embodied in the two exposure analyses models described there is the assumption that CO concentrations within a given environmental setting are a constant function over time and space of its associated monitor site concentration. Thus, transformation matrices which have the study area monitor sites as one dimension, the five environmental settings as the other dimension, and numerical constants as entries can formally represent the transformation of monitor site setting concentrations.

Although such a matrix is a big step in the right direction from assuming that monitored concentrations straightforwardly reflect actual exposure levels, the degree of abstraction from reality is still significant. Also, many matrix entries are mainly judgmental estimates at this time. Hence, rather than estimating single transformation matricies, an upper bound matrix and a lower bound matrix are estimated for each city.

For the present purpose urban areas are divided into the following five (exhaustive) environmental settings:

1. Indoor at Work
2. Other Indoor
3. Inside Transportation Vehicle
4. Other Transport Along Roads
5. Other Outdoors.

Table 1(a) gives the upper bound exposure matrix for Washington, D.C. and Table 1(b) gives the lower bound matrix. Similar upper and lower bound

Table 1. CO Concentration Transformation Matrices; Washington, D.C.

(a) Upper Bound

	μE1	μE2	μE3	μE4	μE5
Site 1	1.0	1.0	2.5	1.7	0.95
Site 2	1.0	1.0	2.3	1.7	0.93
Site 3	1.0	1.0	2.3	1.6	0.93
Site 4	1.0	1.0	2.5	1.7	0.95
Site 5	1.0	1.0	2.3	1.6	0.93
Site 6	1.0	1.0	2.0	1.5	0.90
Site 7	1.0	1.0	2.0	1.5	0.90
Site 8	1.0	1.0	2.0	1.5	0.90
Site 9	1.0	1.0	2.0	1.5	0.90
Site 10	1.0	1.0	2.0	1.5	0.90
Site 11	1.0	1.0	2.0	1.5	0.90

(b) Lower Bound

	μE1	μE2	μE3	μE4	μE5
Site 1	.42	.49	1.0	.85	.50
Site 2	.50	.54	1.0	.80	.40
Site 3	.50	.54	1.0	.80	.40
Site 4	.42	.49	1.0	.85	.50
Site 5	.50	.54	1.0	.80	.40
Site 6	.59	.62	1.0	.75	.33
Site 7	.61	.62	1.0	.75	.33
Site 8	.59	.62	1.0	.75	.33
Site 9	.59	.62	1.0	.75	.33
Site 10	.61	.62	1.0	.75	.33
Site 11	.50	.62	1.0	.75	.33

exposure matrices were developed for the eight other cities and towns included in the analysis. Environmental setting n is represented by (μEn).

The first environmental setting is "Indoor at Work." Ordinarily CO levels are lower indoors than outdoors, particularly on higher floors of a building. (Recall that the present analysis does not include indoor sources such as cigarette smoke.) Hence, 1.0 is taken to be the upper bound factor for all sites.

For the lower bound factor a calculation was made based on: (a) estimates of the percentages of buildings with various numbers of floors in the area associated with a given monitoring site, and (b) some data on the decrease in CO levels as a function of how high in the building the measurement is made [14]. Table 2 gives estimates of the percentages of buildings with various numbers of floors for the eleven Washington, D.C. sites. Basements were not included in the calculation. Table 3 gives a lower bound estimate of the multiplicative factor associated with each floor.

Now, consider site 1 in table 2. From the estimates for site 1 in table 2 and the multiplicative factors in table 3 we can calculate a weighted lower bound multiplicative factor for site 1 in which the weights are determined by the relative number of floors. An important point in this calculation is that every building has a first floor, all buildings at least two stories tall have a second floor, all buildings at least three stories tall have a third floor, and so on. The calculation is as follows:

$$100 \times .9 = 90$$

$$(100 - 20 =)\ 80 \times .4 = 32$$

$$(\ 80 - 25 =)\ 55 \times .25 = 13.75$$

$$(\ 55 - 15 =)\ 40 \times .18 = 7.2$$

$$(\ 40 - 10 =)\ 30 \times .14 = 4.2$$

Table 2. Estimated Distribution of Building Heights (Percentages): Indoor at Work; Washington, D.C.

	Floor									
	1	2	3	4	5	6	7	8	9	$\geq$ 10
Site 1	20	25	15	10	8	7	5	3	2	5
Site 2	30	35	10	9	6	3	2	2	1	2
Site 3	30	35	10	9	6	3	2	2	1	2
Site 4	20	25	15	10	8	7	5	3	2	5
Site 5	30	35	10	9	6	3	2	2	1	2
Site 6	40	40	10	3	3	1	1	1	-	1
Site 7	40	40	10	5	2	2	2	-	-	-
Site 8	40	40	10	3	3	1	1	1	-	1
Site 9	40	40	10	3	3	1	1	1	-	1
Site 10	40	40	10	5	2	2	1	-	-	-
Site 11	40	40	10	3	3	1	1	1	1	1

Table 3. Lower Bound Multiplicative Factors

	Floor									
	1	2	3	4	5	6	7	8	9	10
Factor	.9	.4	.25	.18	.14	.11	.10	.10	.10	.10

$$(30 - 8 =) 22 \times .11 = 2.4$$

$$(22 - 7 =) 15 \times .10 = 1.5$$

$$(15 - 5 =) 10 \times .10 = 1.0$$

$$(10 - 3 =) 7 \times .10 = 0.7$$

$$(7 - 2 =) \underset{S_f=364}{5} \times \underset{\Sigma\delta_i=153.25}{.10 = 0.5}$$

$$\delta_{LB} = \frac{\Sigma\delta_i}{S_f} = \frac{153.25}{364} = .42$$

This weighted factor is the entry in Table 1(b) for site 1. The above calculation is a sample of the type of calculation used to get the entries for the first environmental setting, Indoor at Work, in Table 1(b).

The second environmental setting is "Other Indoor." The same reasoning is used to obtain both the upper bound and lower bound multiplicative factors for environmental setting 2 as for environmental setting 1. Table 4 gives estimates of the percentages of buildings with various numbers of floors that contain people who are in environmental setting 2.

Environmental setting 3 is "Inside Transportation Vehicles." Studies have shown that monitor readings tend to underestimate average CO exposure inside transportation vehicles, so 1.0 is taken to be the lower bound factor for all sites. One study in Boston, a city approximately the same size as Washington, D.C., found the average exposure to be 2.1 times monitor readings [15]. So 2.5 was chosen as the upper bound factor for downtown sites, 2.3 for sites between downtown and suburban, and 2.0 for suburban sites.

Environmental setting 4 is "Other Transport Along Roads." The results of three studies, [16], [17], and [18], are factored into the determination of the upper bound and the lower bound factors for this environmental setting.

Table 4. Estimated Distribution of Building Heights (Percentages): Other Indoor; Washington, D.C.

	Floor									
	1	2	3	4	5	6	7	8	9	≥ 10
Site 1	20	40	15	10	6	2	2	2	1	2
Site 2	35	40	10	4	3	2	2	2	1	1
Site 3	35	40	10	4	3	2	2	2	1	1
Site 4	20	40	15	10	6	2	2	2	1	2
Site 5	35	40	10	4	3	2	2	2	1	1
Site 6	40	45	8	3	1	1	1	-	-	1
Site 7	40	45	8	3	1	1	1	-	-	1
Site 8	40	45	8	3	1	1	1	-	-	1
Site 9	40	45	8	3	1	1	1	-	-	1
Site 10	40	45	8	3	1	1	1	-	-	1
Site 11	40	45	8	3	1	1	1	-	-	1

Environmental setting 5 is "Other Outdoors." Both the upper bound factors and the lower bound factors are judgments based on line source dispersion models [19] and scattered measurements [20]. Indications are that CO concentrations are definitely lower in outdoor settings away from roadways, so even the upper bound factors are made less than 1.0.

APPENDIX D

COMPUTER PROGRAMS FOR CO EXPOSURE MODELS

PL/I Program for 1-Hour CO Exposures

```
PL1 7R1A SL74R1 10/11/79 18:22:34 (->0)


@ADD.PLF      $SOURCE.EXP0-2              . ADD THE PROGRAM
    1.  0       1  EXP0_2:    PROCEDURE OPTIONS (MAIN);
    2.  1       2          DEFAULT (FLOAT % BINARY & ^ CONSTANT) PRECISION(60);
    3.  1       3          DECLARE NUMBER_OF_MONITORS       FIXED BINARY STATIC;
    4.  1       4          DECLARE CONCENTRATION_SUB        FIXED BINARY STATIC;
    5.  1       5          DECLARE HOUR                     FIXED BINARY STATIC;
    6.  1       6          DECLARE SEASON                   FIXED BINARY STATIC;
    7.  1       7          DECLARE DAY_OF_WEEK              FIXED BINARY STATIC;
    8.  1       8          DECLARE MONITOR                  FIXED BINARY STATIC;
    9.  1       9          DECLARE MICRO_ENVIRONMENT        FIXED BINARY STATIC;
   10.  1      10          DECLARE ACTIVITY                 FIXED BINARY STATIC;
   11.  1      11          DECLARE LEVEL                    FIXED BINARY STATIC;
   12.  1      12          DECLARE DAY                      FIXED BINARY STATIC;
   13.  1      13          DECLARE REGION                   FIXED BINARY STATIC;
   14.  1      14          DECLARE METEOROLOGY              FIXED BINARY STATIC;
   15.  1      15          DECLARE TYPE                     FIXED BINARY STATIC;
   16.  1      16          DECLARE MONITORS(20,8)           FLOAT BINARY STATIC;
   17.  1      17  /*
   18.                          MONITORS (MONITOR, VALUE)
   19.
   20.                              VALUE = 1 => RATIO FOR MICRO-ENVIRONMENT 1
   21.                              VALUE = 2 => RATIO FOR MICRO-ENVIRONMENT 2
   22.                              VALUE = 3 => RATIO FOR MICRO-ENVIRONMENT 3
   23.                              VALUE = 4 => RATIO FOR MICRO-ENVIRONMENT 4
   24.                              VALUE = 5 => RATIO FOR MICRO-ENVIRONMENT 5
   25.                              VALUE = 6 => FRACTION OF TOTAL POPULATION AT THIS SITE
   26.                              VALUE = 7 => REDUCTION FACTOR AT SITE TO MEET STANDARD
   27.                              VALUE = 8 => CHARACTERISTIC VALUE FOR THE SITE
   28.
   29.
   30.                      */
   31.                 DECLARE SITES(20)                CHAR(12) STATIC;
   32.  1      18          DECLARE STANDARD                 FLOAT BINARY STATIC;
   33.  1      19          DECLARE STANDARD_NAME            CHAR(6) STATIC INIT (* AS IS*);
   34.  1      20          DECLARE CHARACTERISTIC_VALUE     FLOAT BINARY STATIC;
   35.  1      21          DECLARE BACKGROUND               FLOAT BINARY STATIC;
   36.  1      22          DECLARE TOTAL_POPULATION         FLOAT BINARY STATIC;
   37.  1      23          DECLARE FRACTION_EXCEEDING       FLOAT BINARY STATIC;
   38.  1      24          DECLARE REDUCTION_NEEDED         FLOAT BINARY STATIC;
   39.  1      25          DECLARE CONCENTRATIONS(20)       FLOAT BINARY STATIC;
   40.  1      26          DECLARE NUMBER_OF_CONCENTRATIONS FIXED BINARY;
   41.  1      27          DECLARE ACTIVITY_LEVELS(5,3)     FLOAT BINARY STATIC;
   42.  1      28          DECLARE DAYS_IN_INTERVAL(3)      FLOAT BINARY STATIC INIT (
   43.                                                       5., 1., 1.);
   44.  1      29          DECLARE WEIBULL_DELTA            FLOAT BINARY STATIC;
   45.  1      30          DECLARE GEOMETRIC_MEAN           FLOAT BINARY STATIC;
   46.  1      31          DECLARE (F, T, X)                FLOAT BINARY STATIC;
   47.  1      32  /*
   48.
   49.                          TERMS IN THE LOG - NORMAL INTEGRATION
   50.
   51.                      */
```

```
                DECLARE B(5)                    FLOAT BINARY STATIC INIT(
                                                +0.31938153,
                                                -0.356563782,
                                                +1.781477937,
                                                -1.821255978,
                                                +1.330274429);
     1      33  /*

          THE EXPANSION COEFFICIENTS FOR THE INTEGRATION

                */
                DECLARE NEGATIVE_X              BIT(1) STATIC;
     1      34  DECLARE AIR_QUALITY(20,25,2)    FLOAT BINARY STATIC;
     1      35  /*

          AIR_CUALITY (MONITOR, HOUR, VALUE)


              HOUR = 25 => OVERALL VALUES

              VALUE = 1 => GEOMETRIC DEVIATION
              VALUE = 2 => GEOMETRIC MEAN



                */
                DECLARE HOUR_25                 FIXED BINARY STATIC INIT (25);
     1      36  DECLARE CORRECTION_1(20)        FLOAT BINARY STATIC;
     1      37  DECLARE CORRECTION_2(20)        FLOAT BINARY STATIC;
     1      38  DECLARE CITY_NAME               CHAR(11) STATIC;
     1      39  DECLARE CITY_NUMBER(4)          FIXED BINARY STATIC;
     1      40  DECLARE SITE_NUMBER(4)          FIXED BINARY STATIC;
     1      41  DECLARE CARD_NUMBER(4)          FIXED BINARY STATIC;
     1      42  DECLARE HOUR_TYPE(4)            FIXED BINARY STATIC;
     1      43  DECLARE EXPOSURES(20,3)         FLOAT BINARY STATIC;
     1      44  /*

          EXPOSURES (CONCENTRATION, ACTIVITY LEVEL)

                */
                DECLARE TOTAL_EXPOSURE          FLOAT BINARY STATIC;
     1      45  DECLARE EXP                     BUILTIN;
     1      46  DECLARE LOG                     BUILTIN;
     1      47  DECLARE MAX                     BUILTIN;
     1      48  DECLARE SYSPRINT                FILE OUTPUT STREAM PRINT
                                                ENV (CONSECUTIVE APRINT RECSIZE (132)
                                                TOPMARGIN(6) BOTMARGIN (0) PAGSIZE (66));
     1      49  DECLARE SYSIN                   FILE INPUT STREAM
                                                ENV (CONSECUTIVE AREAD RECSIZE (80));
     1      50  DECLARE EXPO                    FILE INPUT STREAM
                                                ENV (CONSECUTIVE AREADA RECSIZE (132));
     1      51  DECLARE DUMP                    FILE OUTPUT STREAM PRINT
                                                ENV (CONSECUTIVE APRNTA RECSIZE (132)
                                                TOPMARGIN(6) BOTMARGIN (0) PAGSIZE (66));
     1      52  DECLARE SUMS                    FILE OUTPUT STREAM PRINT
                                                ENV (CONSECUTIVE APRNTA RECSIZE (80)
                                                TOPMARGIN(0) BOTMARGIN (0) PAGSIZE (44));
```

```
                                                        ENTRY (BIT(36));
110.  1     54          DECLARE OPTIONS                 BIT(36) STATIC EXTERNAL;
111.  1     55          DECLARE T_OPT                   BIT(1) STATIC EXTERNAL;
112.  1     56          DECLARE DAILY_STANDARD          BIT(1) STATIC;
113.  1     57    %PAGE;
```

```
                CALL EROPT(OPTIONS);
1       58      T_OPT = SUBSTR(OPTIONS,30,1);
1       59      OPEN FILE (SYSPRINT);
1       60    IF (T_OPT) THEN
                OPEN FILE (DUMP);
1       62      OPEN FILE (SYSIN);
1       63      ON ENDFILE (SYSIN) GO TO FINISHED;
1       64      ON UNDERFLOW BEGIN; END;
1       66      GET EDIT (NUMBER_OF_MONITORS, BACKGROUND,
                    TOTAL_POPULATION, STANDARD_TYPE)
                    (COL(1), F(2), X(1), F(5), F(10), F(1));
1       67    IF (T_OPT) THEN
                PUT FILE (DUMP) DATA (NUMBER_OF_MONITORS, BACKGROUND,
                    TOTAL_POPULATION)           ;
1       69      IF (STANDARD_TYPE = 1) THEN
                    DAILY_STANDARD = '1'B;
1       71          ELSE
                    DAILY_STANDARD = '0'B;
1       72      GET EDIT (NUMBER_OF_CONCENTRATIONS)
                    (COL(1), F(2));
1       73      DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
1   1   74          GET EDIT (CONCENTRATIONS(CONCENTRATION_SUB))
                        (COL(1), F(10));
1   1   75          END;
1       76    IF (T_OPT) THEN
                PUT FILE (DUMP) SKIP(2);
1       78    IF (T_OPT) THEN
                PUT FILE (DUMP) DATA (NUMBER_OF_CONCENTRATIONS, CONCENTRATIONS);
1       80      DO MONITOR = 1 TO NUMBER_OF_MONITORS;
1   1   81      GET EDIT (CITY_NAME,
                    CITY_NUMBER(1), SITE_NUMBER(1), HOUR_TYPE(1), CARD_NUMBER(1),
                    (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
                    DO HOUR = 1 TO 6),
                    CITY_NUMBER(2), SITE_NUMBER(2), HOUR_TYPE(2), CARD_NUMBER(2),
                    (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
                    DO HOUR = 7 TO 13),
                    CITY_NUMBER(3), SITE_NUMBER(3), HOUR_TYPE(3), CARD_NUMBER(3),
                    (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
                    DO HOUR = 14 TO 20),
                    CITY_NUMBER(4), SITE_NUMBER(4), HOUR_TYPE(4), CARD_NUMBER(4),
                    (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
                    DO HOUR = 21 TO 24, 25),
                    CORRECTION_1(MONITOR), CORRECTION_2(MONITOR))
                    (COL(1), A(11), F(2), F(3), F(2), F(2), 12(F(5)),
                    3(COL(1), F(3), F(3), F(2), F(2), 14(F(5))));
1   1   82          IF (T_OPT) THEN
                    PUT FILE (DUMP) PAGE;
1   1   84          IF (T_OPT) THEN
                    PUT FILE (DUMP) DATA  (CITY_NAME, CITY_NUMBER, SITE_NUMBER,
                        CARD_NUMBER, HOUR_TYPE);
1   1   86          END;                        /* END OF READING AIR_QUALITY DATA */
1       87          DO MONITOR = 1 TO NUMBER_OF_MONITORS;
1   1   88              GET EDIT ((MONITORS(MONITOR,MICRO_ENVIRONMENT)
                            DO MICRO_ENVIRONMENT = 1 TO 6), /* 6 IS THE FRACTION POP */
                            SITES(MONITOR))
                            (COL(21), SF(5,2), F(6,1), COL(55), A(12));
1   1   89                  PUT PAGE EDIT ('SITE ', SITES(MONITOR),
```

```
172.                                   '          STANDARD      GEOMETRIC', 'HOUR  ',
173.                                   'DEVIATION       MEAN          ',
174.                                   'DEVIATION       MEAN          ',
175.                                   'DEVIATION       MEAN')
176.                                   (COL(1), A, A, LINE(3), A, A, LINE(4), A, A, A, A);
177.  1  1    90                  PUT SKIP(2);
178.  1  1    91                  DO HOUR = 1 TO 24;
179.  1  2    92                      PUT EDIT (HOUR, AIR_QUALITY(MONITOR, HOUR, 1),
180.                                       AIR_QUALITY(MONITOR, HOUR, 2))
181.                                       (COL(1), F(3), F(10,3), F(12,3));
182.  1  2    93                      AIR_QUALITY(MONITOR, HOUR, 1) =
183.                                       AIR_QUALITY(MONITOR, HOUR, 1) * CORRECTION_1(MONITOR);
184.  1  2    94                      AIR_QUALITY(MONITOR, HOUR, 2) =
185.                                       AIR_QUALITY(MONITOR, HOUR, 2) * CORRECTION_2(MONITOR);
186.  1  2    95                      PUT EDIT (AIR_QUALITY(MONITOR, HOUR, 1),
187.                                       AIR_QUALITY(MONITOR, HOUR, 2))
188.                                       (F(15,3), F(12,3));
189.  1  2    96                      AIR_QUALITY(MONITOR, HOUR, 2) =
190.                                       EXP (AIR_QUALITY(MONITOR, HOUR, 2));
191.  1  2    97                      PUT EDIT (AIR_QUALITY(MONITOR, HOUR, 1),
192.                                       AIR_QUALITY(MONITOR, HOUR, 2))
193.                                       (F(15,3), F(12,3));
194.  1  2    98                  END;
195.  1  1    99                  PUT SKIP(2) EDIT ('OVERALL', AIR_QUALITY(MONITOR, 25, 1),
196.                                   AIR_QUALITY(MONITOR, HOUR, 2))
197.                                   (COL(1), A, F(6,3), F(12,3));
198.  1  1   100                  AIR_QUALITY(MONITOR, 25, 2) =
199.                                   EXP (AIR_QUALITY(MONITOR, 25, 2));
200.  1  1   101                  PUT EDIT ( AIR_QUALITY(MONITOR, 25, 1),
201.                                   AIR_QUALITY(MONITOR, HOUR, 2))
202.                                   (COL(62), F(6,3), F(12,3));
203.  1  1   102                  PUT SKIP(3) EDIT (
204.                                   'CORRECTION TO THE STANDARD DEVIATIONS WAS ',
205.                                   CORRECTION_1(MONITOR),
206.                                   '                  CORRECTION TO THE MEANS WAS ',
207.                                   CORRECTION_2(MONITOR))
208.                                   (COL(30), A, F(6,3), COL(30), A, F(6,3));
209.  1  1   103                  MONITORS(MONITOR, 8) = EXP ( LOG (AIR_QUALITY(MONITOR, 25, 2))
210.                                   + 3.686 * AIR_QUALITY(MONITOR, 25, 1));
211.  1  1   104                  CHARACTERISTIC_VALUE = MAX(CHARACTERISTIC_VALUE,
212.                                   MONITORS(MONITOR, 8));
213.  1  1   105                              /* END OF GETTING CHARACTERISTIC VALUES */
214.                                   MONITORS(MONITOR, 7) = 1.0;  /* SET FOR AS IS EXPOSURE */
215.  1  1   106                  END;
216.  1      107              IF (T_OPT) THEN
217.                               PUT FILE (DUMP) PAGE;
218.  1      109              IF (T_OPT) THEN
219.                               PUT FILE (DUMP) DATA (AIR_QUALITY);
220.  1      111                  GO TO OPEN_ACTIVITY_LEVELS;
221.  1      112          NEXT_STANDARD:
222.                               GET EDIT (STANDARD) (COL(1), F(5));
223.  1      113                  PUT STRING (STANDARD_NAME) EDIT (STANDARD) (F(6,2));
224.  1      114                  IF (DAILY_STANDARD) THEN
225.                                   REDUCTION_NEEDED = (CHARACTERISTIC_VALUE * 0.948 - STANDARD) /
226.                                       (CHARACTERISTIC_VALUE * 0.948 - BACKGROUND);
227.  1      116                  ELSE
```

```
228.                        REDUCTION_NEEDED = (CHARACTERISTIC_VALUE - STANDARD) /
229.                            (CHARACTERISTIC_VALUE - BACKGROUND);
230.  1      117          DO MONITOR = 1 TO NUMBER_OF_MONITORS;
231.  1  1   118             MONITORS(MONITOR, 7) = ((MONITORS(MONITOR, 8) - BACKGROUND)
232.                            * (1.0 - REDUCTION_NEEDED) + BACKGROUND) / MONITORS(MONITOR, 8);
233.  1  1   119             END;                          /* END OF SITE REDUCTIONS */
234.  1      120       IF (T_OPT) THEN
235.                     PUT FILE (DUMP) PAGE;
236.  1      122       IF (T_OPT) THEN
237.                     PUT FILE (DUMP) DATA (MONITORS, REDUCTION_NEEDED, CHARACTERISTIC_VALUE);
238.  1      124  %PAGE;
```

```
240.                        OPEN FILE (EXPO);
241.  1       125           ON ENDFILE (EXPO) GO TO WRITE_REPORT;
242.  1       126           EXPOSURES = 0;
243.  1       127     GET_ACTIVITY_LEVELS:
244.                        GET FILE (EXPO) EDIT (REGION, METEOROLOGY, SEASON, DAY, TYPE,
245.                            HOUR, ((ACTIVITY_LEVELS(ACTIVITY, LEVEL)
246.                            DO LEVEL = 1 TO 3)
247.                            DO ACTIVITY = 1 TO 5))
248.                            (COL(1), 2F(1), X(2), 3F(1), F(2), X(1), 15F(5,1));
249.  1       128           ACTIVITY_LEVELS = 0.01 * ACTIVITY_LEVELS;
250.  1       129         IF (T_OPT) THEN
251.                        PUT FILE (DUMP) PAGE;
252.  1       131         IF (T_OPT) THEN
253.                        PUT FILE (DUMP) DATA (REGION, METEOROLOGY, SEASON, DAY, TYPE,
254.                            HOUR, ACTIVITY_LEVELS);
255.  1       133           DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
256.  1   1   134         IF (T_OPT) THEN
257.                        PUT FILE (DUMP) DATA (CONCENTRATION_SUB);
258.  1   1   136           DO MONITOR = 1 TO NUMBER_OF_MONITORS;
259.  1   2   137         IF (T_OPT) THEN
260.                        PUT FILE (DUMP) DATA (MONITOR);
261.  1   2   139           DO MICRO_ENVIRONMENT = 1 TO 5;
262.  1   3   140         IF (T_OPT) THEN
263.                        PUT FILE (DUMP) DATA (MICRO_ENVIRONMENT);
264.  1   3   142         IF (T_OPT) THEN
265.                        PUT FILE (DUMP) SKIP;
266.  1   3   144     LOG_NORMAL_DISTRIBUTION:
267.                        GEOMETRIC_MEAN = MONITORS(MONITOR, 7)
268.                            * MONITORS(MONITOR, MICRO_ENVIRONMENT)
269.                            * AIR_QUALITY(MONITOR, HOUR, 2);
270.  1   3   145           X = (LOG(CONCENTRATIONS(CONCENTRATION_SUB))
271.                            - LOG(GEOMETRIC_MEAN)) /AIR_QUALITY(MONITOR, HOUR, 1);
272.  1   3   146           IF (X < 0) THEN DO;
273.  1   3   148               NEGATIVE_X = '1'B;
274.  1   3   149               X = - X;
275.  1   3   150               END;
276.  1   3   151           ELSE DO;
277.  1   3   152               NEGATIVE_X = '0'B;
278.  1   3   153               END;
279.  1   3   154           T = 1.0 / (1.0 + 0.2316419 * X);
280.  1   3   155           F = 0.3989423 * EXP(-(X * X / 2.0));
281.  1   3   156           FRACTION_EXCEEDING =
282.                            ((((B(5) * T + B(4)) * T + B(3)) * T + B(2)) * T + B(1)) * T * F;
283.  1   3   157           IF (NEGATIVE_X) THEN
284.                            FRACTION_EXCEEDING = 1. - FRACTION_EXCEEDING;
285.  1   3   159           GO TO FRACTION_EXCEEDING_FOUND;
286.  1   3   160     FRACTION_EXCEEDING_FOUND:
287.                      IF (T_OPT) THEN
288.                        PUT FILE (DUMP) SKIP;
289.  1   3   162         IF (T_OPT) THEN
290.                        PUT FILE (DUMP) DATA (FRACTION_EXCEEDING);
291.  1   3   164           DO LEVEL = 1 TO 3;
292.  1   4   165           EXPOSURES(CONCENTRATION_SUB, LEVEL) = EXPOSURES(CONCENTRATION_SUB, LEVEL)
293.                            + FRACTION_EXCEEDING * ACTIVITY_LEVELS(MICRO_ENVIRONMENT, LEVEL)
294.                            * DAYS_IN_INTERVAL(DAY) * MONITORS(MONITOR, 6);
295.  1   4   166               END;                          /* END OF LEVEL                */
```

```
296.  1  3  167            END;                          /* END OF MICRO_ENVIRONMENT    */
297.  1  2  168            END;                          /* END OF MONITOR              */
298.  1  1  169            END;                          /* END OF CONCENTRATION_SUB    */
299.  1     170      IF (T_OPT) THEN
300.                    PUT FILE (DUMP) SKIP(2);
301.  1     172      IF (T_OPT) THEN
302.                    PUT FILE (DUMP) DATA (EXPOSURES);
303.  1     174         GO TO GET_ACTIVITY_LEVELS;
304.  1     175   %PAGE;
```

```
                WRITE_REPORT:
                    PUT PAGE EDIT ('STANDARD OF ', STANDARD_NAME, ' WITH BACKGROUND OF ',
                        BACKGROUND, CITY_NAME,
                        '                  < - G A M M A     V A L U E S - >',
                        '                  INDOORS    OTHER      TRANS      TRANS          ',
                        '     FRACTION     REDUCTION   CHARACTERISTIC',
                        ' S  I  T  E    WORK      INDOORS   VEHICLE    OTHER    OUTSID',
                        'E   POPULATION       FACTOR          HIGH      ')
                        (LINE(5), COL(35), A, A, A, F(6,2), LINE(7), COL(50), A,
                        LINE(10), A, LINE(12), A, A, LINE(13), A, A);
                    PUT SKIP(2);
                    DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                        PUT SKIP EDIT (SITES(MONITOR), (MONITORS(MONITOR, J) DO J = 1 TO 8))
                            (COL(1), A(12), F(8,3), 4(F(10,3)), F(12,4), F(14,4), F(13,3));
                        END;
                    PUT PAGE;
                    PUT EDIT ('PERSON HOURS OF EXPOSURE FOR A STANDARD OF ',
                        STANDARD_NAME, ' WITH BACKGROUND OF ', BACKGROUND, CITY_NAME,
            'CONCENTRATION                                    LOW          MEDIUM          HIGH',
            '   EXCEEDED            TOTAL              ACTIVITY       ACTIVITY       ACTIVITY'
                        )
                        (LINE(5), COL(8), A, A, A, F(6,2),
                        LINE(7), COL(30), A,
                        LINE(9), A, LINE(10), A);
                    PUT SKIP(2);
                    DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
                        TOTAL_EXPOSURE = 0.0;
                        DO LEVEL = 1 TO 3;
                            EXPOSURES(CONCENTRATION_SUB, LEVEL) =
                                EXPOSURES(CONCENTRATION_SUB, LEVEL)
                                * 17.4 * TOTAL_POPULATION;
                            TOTAL_EXPOSURE = TOTAL_EXPOSURE
                            + EXPOSURES(CONCENTRATION_SUB, LEVEL);
                            END;                        /* END OF SUMMING EXPOSURE */
                        PUT EDIT (CONCENTRATIONS(CONCENTRATION_SUB),
                        TOTAL_EXPOSURE,
                            EXPOSURES(CONCENTRATION_SUB, 1),
                            EXPOSURES(CONCENTRATION_SUB, 2),
                            EXPOSURES(CONCENTRATION_SUB, 3))
                            (COL(1), F(9), X(5), E(15,3), X(5), 3E(15,3));
                        PUT SKIP(2);
                        END;                            /* END CONCENTRATION_SUB */
                    CLOSE FILE (EXPO);
                    PUT FILE (SUMS) EDIT (STANDARD_NAME,
                        BACKGROUND, CONCENTRATIONS, CITY_NAME, EXPOSURES)
                        (COL(1), A(6), F(10,3), COL(1),20(F(10,3)), COL(1), A(11),
                        COL(1), 60(E(20,8)));
                    GO TO NEXT_STANDARD;
                FINISHED:
                    CLOSE FILE (SYSPRINT);
                    CLOSE FILE (SUMS);
                IF (T_OPT) THEN
                    CLOSE FILE (DUMP);
                    CLOSE FILE (SYSIN);
                    RETURN;
                    END;                                /* END PROGRAM */
```

C R O S S R E F E R E N C E L I S T I N G

```
ACTIVITY              DECLARED(10) ALLOC($(2) 000007 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                  SET     127
                 USED     127
ACTIVITY_LEVELS       DECLARED(27) ALLOC($(2) 000677 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                        DIMENSION(1:5,1:3) ALIGNED
                  SET     127   128
                 USED     128   132   165
AIR_QUALITY           DECLARED(34) ALLOC($(2) 000770 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                        DIMENSION(1:20,1:25,1:2) ALIGNED
                  SET      81    81    81    81    81    81    81    93    94    96   100
                 USED      92    92    93    94    95    95    96    97    97    99    99   100   101   101   103   103   110   144
                         145
B                     DECLARED(32) ALLOC($(2) 000755 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:5)
                        ALIGNED INITIAL
                  SET      32
                 USED     156   156   156   156   156
BACKGROUND            DECLARED(21) ALLOC($(2) 000617 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                  SET      66
                 USED      68   115   116   118   118   175   181   193
CARD_NUMBER           DECLARED(41) ALLOC($(2) 005044 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                        ALIGNED
                  SET      81    81    81    81
                 USED      85
CHARACTERISTIC_VALUE  DECLARED(20) ALLOC($(2) 000615 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                  SET     104
                 USED     104   115   115   116   116   123
CITY_NAME             DECLARED(38) ALLOC($(2) 005031 BIT 1, 99 BITS) NONVARYING CHARACTER(11) STATIC VARIABLE INTERNAL UNALIGNED
                  SET      81
                 USED      85   175   181   193
CITY_NUMBER           DECLARED(39) ALLOC($(2) 005034 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                        ALIGNED
                  SET      81    81    81    81
                 USED      85
CONCENTRATIONS        DECLARED(25) ALLOC($(2) 000627 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                        ALIGNED
                  SET      74
                 USED      79   145   189   193
CONCENTRATION_SUB     DECLARED(4) ALLOC($(2) 000001 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                  SET      73   133   183
                 USED      74   135   145   165   165   186   186   187   189   189   189   189
CORRECTION_1          DECLARED(36) ALLOC($(2) 004711 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                        ALIGNED
                  SET      81
                 USED      93   102
CORRECTION_2          DECLARED(37) ALLOC($(2) 004761 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                        ALIGNED
                  SET      81
                 USED      94   102
DAILY_STANDARD        DECLARED(56) ALLOC($(2) 005246 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE INTERNAL UNALIGNED
                  SET      70    71
                 USED     114
DAY                   DECLARED(12) ALLOC($(2) 000011 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                  SET     127
                 USED     132   165
```

```
                    SET      28
                   USED     165
DAY_OF_WEEK              DECLARED(7) ALLOC($(2) 000004 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
               NOT REF
DUMP                     DECLARED(51) ALLOC($(12) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
                   USED      61    68    77    79    83    85   108   110   121   123   130   132   135   138   141   143   161   163
                             171   173   198
EROPT                    DECLARED(53) ENTRY CONSTANT EXTERNAL
                    SET      57
           NOT USED
EXP                      DECLARED(45) BUILTIN
               NOT SET
                   USED      96   100   103   155
EXPO                     DECLARED(50) ALLOC($(11) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM INPUT
                   USED     124   125   127   192
EXPOSURES                DECLARED(43) ALLOC($(2) 005054 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                              DIMENSION(1:20,1:3) ALIGNED
                    SET     126   165   186
                   USED     165   173   186   187   189   189   189   193
EXPO_2                   DECLARED(1) ALLOC($(1) 004714 ) ENTRY CONSTANT EXTERNAL
               NOT REF
F                        DECLARED(31) ALLOC($(2) 000747 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                    SET     155
                   USED     156
FINISHED                 DECLARED(195) ALLOC($(1) 004631 ) LABEL CONSTANT INTERNAL
                   USED      63
FRACTION_EXCEEDING       DECLARED(23) ALLOC($(2) 000623 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                    SET     156   158
                   USED     158   163   165
FRACTION_EXCEEDING_FOUND  DECLARED(160) ALLOC($(1) 003624 ) LABEL CONSTANT INTERNAL
                   USED     159
GEOMETRIC_MEAN           DECLARED(30) ALLOC($(2) 000745 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                    SET     144
                   USED     145
GET_ACTIVITY_LEVELS      DECLARED(127) ALLOC($(1) 002633 ) LABEL CONSTANT INTERNAL
                   USED     174
HOUR                     DECLARED(5) ALLOC($(2) 000002 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                    SET      81    81    81    81    91   127
                   USED      81    81    81    81    81    81    81    81    92    92    92    93    93    94    94    95    95    96
                              96    97    97    99   101   132   144   145
HOUR_25                  DECLARED(35) ALLOC($(2) 004710 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                              INITIAL
                    SET      35
           NOT USED
HOUR_TYPE                DECLARED(42) ALLOC($(2) 005050 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                              ALIGNED
                    SET      81    81    81    81
                   USED      85
J                        IMPLICIT ALLOC(000021 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL AUTOMATIC VARIABLE INTERNAL ALIGNED
                    SET     178
                   USED     178
LEVEL                    DECLARED(11) ALLOC($(2) 000010 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                    SET     127   164   185
                   USED     127   165   165   165   186   186   187
LOG                      DECLARED(46) BUILTIN
               NOT SET
```

```
                USED    103   145   145
LOG_NORMAL_DISTRIBUTION  DECLARED(144) ALLOC($(1) 003364 ) LABEL CONSTANT INTERNAL
            NOT REF
MAX                 DECLARED(47) BUILTIN
            NOT SET
                USED    104
METEOROLOGY         DECLARED(14) ALLOC($(2) 000013 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    127
                USED    132
MICRO_ENVIRONMENT   DECLARED(9) ALLOC($(2) 000006 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     88   139
                USED     88   141   144   165
MONITOR             DECLARED(8) ALLOC($(2) 000005 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     80    87   117   136   177
                USED     81    81    81    81    81    81    81    81    81    81    88    88    89    92    92    93    93    93
                         94    94    94    95    95    96    96    97    97    99    99   100   100   101   101   102   102   103
                        103   103   104   105   118   118   118   138   144   144   144   145   165   178   178
MONITORS            DECLARED(16) ALLOC($(2) 000015 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                      DIMENSION(1:20,1:8) ALIGNED
                 SET     88   103   105   118
                USED    104   118   118   123   144   144   165   178
NEGATIVE_X          DECLARED(33) ALLOC($(2) 000767 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE INTERNAL UNALIGNED
                 SET    148   152
                USED    157
NEXT_STANDARD       DECLARED(112) ALLOC($(1) 002326 ) LABEL CONSTANT INTERNAL
                USED    194
NUMBER_OF_CONCENTRATIONS  DECLARED(26) ALLOC(000017 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL AUTOMATIC VARIABLE INTERNAL ALIGNED
                 SET     72
                USED     73    79   133   183
NUMBER_OF_MONITORS  DECLARED(3) ALLOC($(2) 000000 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     66
                USED     68    80    87   117   136   177
OPEN_ACTIVITY_LEVELS  DECLARED(124) ALLOC($(1) 002541 ) LABEL CONSTANT INTERNAL
                USED    111
OPTIONS             DECLARED(54) ALLOC($(14) 000000 BIT 1, 36 BITS) NONVARYING BIT(36) STATIC VARIABLE EXTERNAL UNALIGNED
            NOT SET
                USED     58    57
REDUCTION_NEEDED    DECLARED(24) ALLOC($(2) 000625 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    115   116
                USED    118   123
REGION              DECLARED(13) ALLOC($(2) 000012 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    127
                USED    132
SEASON              DECLARED(6) ALLOC($(2) 000003 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    127
                USED    132
SITES               DECLARED(17) ALLOC($(2) 000515 BIT 1, 108 BITS) NONVARYING CHARACTER(12) STATIC VARIABLE INTERNAL
                      DIMENSION(1:20) UNALIGNED
                 SET     88
                USED     89   178
SITE_NUMBER         DECLARED(40) ALLOC($(2) 005040 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                      ALIGNED
                 SET     81    81    81    81
                USED     85
STANDARD            DECLARED(18) ALLOC($(2) 000611 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    112
                USED    113   115   116
```

```
STANDARD_NAME          DECLARED(19) ALLOC($(2) 000613 BIT 1, 54 BITS) NONVARYING CHARACTER(6) STATIC VARIABLE INTERNAL UNALIGNED
                            INITIAL
                   SET      19   113
                  USED     175   181   193
STANDARD_TYPE          IMPLICIT ALLOC(000020 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL AUTOMATIC VARIABLE INTERNAL ALIGNED
                   SET      66
                  USED      69
SUBSTR                 CONTEXTUAL BUILTIN
              NOT SET
                  USED      58
SUMS                   DECLARED(52) ALLOC($(13) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
                  USED     193   196
SYSIN                  DECLARED(49) ALLOC($(10) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM INPUT
                  USED      62    63    66    72    74    81    88   112   199
SYSPRINT               DECLARED(48) ALLOC($(9) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
                  USED      59    89    90    92    95    97    99   101   102   175   176   178   180   181   182   189   190   195
T                      DECLARED(31) ALLOC($(2) 000751 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                   SET     154
                  USED     156   156   156   156   156
TOTAL_EXPOSURE         DECLARED(44) ALLOC($(2) 005244 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                   SET     184   187
                  USED     187   189
TOTAL_POPULATION       DECLARED(22) ALLOC($(2) 000621 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                   SET      66
                  USED      68   186
TYPE                   DECLARED(15) ALLOC($(2) 000014 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                   SET     127
                  USED     132
T_OPT                  DECLARED(55) ALLOC($(15) 00000C BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE EXTERNAL UNALIGNED
                   SET      58
                  USED      60    67    76    78    82    84   107   109   120   122   129   131   134   137   140   142   160   162
                            170   172   197
WEIBULL_DELTA          DECLARED(29) ALLOC($(2) 000743 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
              NOT REF
WRITE_REPORT           DECLARED(175) ALLOC($(1) 004043 ) LABEL CONSTANT INTERNAL
                  USED     125
X                      DECLARED(31) ALLOC($(2) 000753 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                   SET     145   149
                  USED     146   149   154   155   155

**** NO ERRORS OR WARNINGS IN ABOVE PROGRAM
END PL1 3033 IBANK 3402 DBANK
 18:23:31   PL1
 DRUM 00:00:05.129 DISC 00:00:00.792 TAPE 00:00:00.114 I/O  00:00:06.036
 CCER 00:00:07.167 CAU  00:00:04.588 MEMY 00:00:03.094-0025K
```

```
@FLT.L          $MAP.EXP0-2                    . LIST THE MAP INSTRUCTIONS
FLT007 SL73R1 10/11/79 18:23:31 (17.)
000001       013     IN EXP0-2

END FLT.
 18:23:31   ELT
 DRUM 00:00:00.029 DISC 00:00:00.261 TAPE 00:00:00.000 I/O  00:00:00.250
 CCER 00:00:00.501 CAU  00:00:00.000 MEMY 00:00:00.039-0007K
```

PL/I Program for 8-Hour CO Exposures

```
@PL1.OPTRS    XS.EXPO-8
PL1 7R1A SL74R1 11/02/79 08:52:48 (->0)


@ADD.PLE      $SOURCE.EXPO-8              . ADD THE PROGRAM
    1.  0       1  EXPO_8_HR: PROCEDURE OPTIONS (MAIN);
    2.  1       2          DEFAULT (FLOAT & BINARY & ^ CONSTANT) PRECISION(60);
    3.  1       3          DECLARE NUMBER_OF_MONITORS      FIXED BINARY STATIC;
    4.  1       4          DECLARE DISTRIBUTION            FIXED BINARY STATIC;
    5.  1       5  /*
    6.
    7.                         DISTRIBUTION = 1 => WIEBULL
    8.                         DISTRIBUTION = 2 => LOG - NORMAL
    9.
   10.                 */
   11.                 DECLARE WIEBULL                     FIXED BINARY STATIC INIT (1);
   12.  1       6          DECLARE LOG_NORMAL              FIXED BINARY STATIC INIT (2);
   13.  1       7          DECLARE CONCENTRATION_SUB       FIXED BINARY STATIC;
   14.  1       8          DECLARE HOUR                    FIXED BINARY STATIC;
   15.  1       9          DECLARE DAY_OF_WEEK             FIXED BINARY STATIC;
   16.  1      10          DECLARE MONITOR                 FIXED BINARY STATIC;
   17.  1      11          DECLARE MICRO_ENVIRONMENT       FIXED BINARY STATIC;
   18.  1      12          DECLARE LEVEL                   FIXED BINARY STATIC;
   19.  1      13          DECLARE MONITORS(20,8)          FLOAT BINARY STATIC;
   20.  1      14  /*
   21.                         MONITORS (MONITOR, VALUE)
   22.
   23.                             VALUE = 1 => RATIO FOR MICRO-ENVIRONMENT 1
   24.                             VALUE = 2 => RATIO FOR MICRO-ENVIRONMENT 2
   25.                             VALUE = 3 => RATIO FOR MICRO-ENVIRONMENT 3
   26.                             VALUE = 4 => RATIO FOR MICRO-ENVIRONMENT 4
   27.                             VALUE = 5 => RATIO FOR MICRO-ENVIRONMENT 5
   28.                             VALUE = 6 => FRACTION OF TOTAL POPULATION AT THIS SITE
   29.                             VALUE = 7 => REDUCTION FACTOR AT SITE TO MEET STANDARD
   30.                             VALUE = 8 => CHARACTERISTIC VALUE FOR THE SITE
   31.
   32.
   33.                 */
   34.                 DECLARE SITES(20)               CHAR(12) STATIC;
   35.  1      15          DECLARE STANDARD                FLOAT BINARY STATIC;
   36.  1      16          DECLARE STANDARD_NAME           CHAR(6) STATIC INIT (' AS IS');
   37.  1      17          DECLARE CHARACTERISTIC_VALUE    FLOAT BINARY STATIC;
   38.  1      18          DECLARE BACKGROUND.             FLOAT BINARY STATIC;
   39.  1      19          DECLARE TOTAL_POPULATION        FLOAT BINARY STATIC;
   40.  1      20          DECLARE POPULATION(12)          FLOAT BINARY STATIC;
   41.  1      21          DECLARE FRACTION_EXCEEDING      FLOAT BINARY STATIC;
   42.  1      22          DECLARE REDUCTION_NEEDED        FLOAT BINARY STATIC;
   43.  1      23          DECLARE CONCENTRATIONS(20)      FLOAT BINARY STATIC;
   44.  1      24          DECLARE NUMBER_OF_CONCENTRATIONS FIXED BINARY STATIC;
   45.  1      25          DECLARE GEOMETRIC_MEAN          FLOAT BINARY STATIC;
   46.  1      26          DECLARE (F, T, X)               FLOAT BINARY STATIC;
   47.  1      27  /*
   48.
   49.                         TERMS IN THE LOG - NORMAL INTEGRATION
   50.
   51.                 */
```

```
                DECLARE E(5)                    FLOAT BINARY STATIC INIT(
                                                +0.31938153,
                                                -0.356563782,
                                                +1.781477937,
                                                -1.821255978,
                                                +1.330274429);

    THE EXPANSION COEFFICIENTS FOR THE INTEGRATION

*/
DECLARE NEGATIVE_X              BIT(1) STATIC;
DECLARE AIR_QUALITY(NUMBER_OF_MONITORS,-6:169,5)
                                FLOAT BINARY CONTROLLED;

    AIR_QUALITY (MONITOR, HOUR, VALUE)

        HOUR = 169 => OVERALL VALUES

        VALUE = 1 => GEOMETRIC DEVIATION (1 HR DATA)
        VALUE = 2 => GEOMETRIC MEAN OR LOG THERE OF (1 HR DATA)
        VALUE = 3 => REDUCED 1 HR MEAN
        VALUE = 4 => GEOMETRIC DEVIATION (8 HR DATA)
        VALUE = 5 => GEOMETRIC MEAN OR LOG THERE OF (8 HR DATA)

*/
DECLARE HOUR_169                FIXED BINARY STATIC INIT (169);
DECLARE CORRECTION_1(20)        FLOAT BINARY STATIC;
DECLARE CORRECTION_2(20)        FLOAT BINARY STATIC;
DECLARE CORRECTION_4(20)        FLOAT BINARY STATIC;
DECLARE CORRECTION_5(20)        FLOAT BINARY STATIC;
DECLARE CITY_NAME               CHAR(11) STATIC;
DECLARE CITY_NUMBER(4)          FIXED BINARY STATIC;
DECLARE SITE_NUMBER(4)          FIXED BINARY STATIC;
DECLARE CARD_NUMBER(4)          FIXED BINARY STATIC;
DECLARE HOUR_TYPE(4)            FIXED BINARY STATIC;
DECLARE EXPOSURES(20,3)         FLOAT BINARY STATIC;

    EXPOSURES (CONCENTRATION, ACTIVITY LEVEL)

*/
DECLARE TOTAL_EXPOSURE          FLOAT BINARY STATIC;
DECLARE EXP                     BUILTIN;
DECLARE LOG                     BUILTIN;
DECLARE MAX                     BUILTIN;
DECLARE SUBSTR                  BUILTIN;
DECLARE SYSPRINT                FILE OUTPUT STREAM PRINT
                                ENV (CONSECUTIVE APRINT RECSIZE (132)
                                TOPMARGIN(6) BOTMARGIN (0) PAGSIZE (66));

DECLARE SYSIN                   FILE INPUT STREAM
                                ENV (CONSECUTIVE AREAD RECSIZE (80));

DECLARE EXPO                    FILE INPUT STREAM
```

```
109.
110.  1     49        DECLARE DUMP                    ENV (CONSECUTIVE AREADA RECSIZE (132));
                                                     FILE OUTPUT STREAM PRINT
111.                                                 ENV (CONSECUTIVE APRNTA RECSIZE (132)
112.                                                 TOPMARGIN(6) BOTMARGIN (0) PAGSIZE (66));
113.  1     50        DECLARE SUMS                    FILE OUTPUT STREAM PRINT
114.                                                 ENV (CONSECUTIVE APRNTA RECSIZE (80)
115.                                                 TOPMARGIN(6) BOTMARGIN (0) PAGSIZE (66));
116.  1     51        DECLARE FROPT                   ENTRY (BIT(36));
117.  1     52        DECLARE OPTIONS                 BIT(36) STATIC EXTERNAL;
118.  1     53        DECLARE T_OPT                   BIT(1) STATIC EXTERNAL;
119.  1     54        DECLARE O_OPT                   BIT(1) STATIC EXTERNAL;
120.  1     55        DECLARE ACTIVITY_IN(24)         CHAR(2) STATIC;
121.  1     56        DECLARE LEVEL_IN(24)            CHAR(1) STATIC;
122.  1     57        DECLARE ACTIVITYS(-6:168)       FIXED BINARY STATIC;
123.  1     58        DECLARE LEVELS(-6:168)          FIXED BINARY STATIC;
124.  1     59        DECLARE ACTIVITY_NAME(5)        CHAR(2) INIT (
                                                     'IN','OI','TV','CT','OD') STATIC;
125.
126.  1     60        DECLARE LEVEL_NAME(3)           CHAR(1) INIT ('L','M','H') STATIC;
127.  1     61        DECLARE PERCENT_IN_GROUP_IN     FLOAT BINARY STATIC;
128.  1     62        DECLARE PERCENT_IN_GROUP(168)   FLOAT BINARY STATIC;
129.  1     63        DECLARE J                       FIXED BINARY STATIC;
130.  1     64        DECLARE OCCUPATION              FIXED BINARY STATIC;
131.  1     65        DECLARE SMSA                    FIXED BINARY STATIC;
132.  1     66        DECLARE SUB_GROUP               FIXED BINARY STATIC;
133.  1     67        DECLARE STANDARD_TYPE           FIXED BINARY STATIC;
134.  1     68        DECLARE DAILY_STANDARD          BIT(1) STATIC;
135.  1     69  %PAGE;
```

```
136.                    CALL EROFT(OPTIONS);
137.  1        70       T_OPT = SUBSTR(OPTIONS,30,1);
138.  1        71       O_OPT = SUBSTR(OPTIONS,25,1);
139.  1        72       OPEN FILE (SYSPRINT);
140.  1        73       OPEN FILE (SUMS);
141.  1        74     IF (T_OPT ! O_OPT) THEN
142.                       OPEN FILE (DUMP);
143.  1        76       OPEN FILE (SYSIN);
144.  1        77       ON ENDFILE (SYSIN) GO TO FINISHED;
145.  1        78       ON UNDERFLOW BEGIN; END;
146.  1        80       GET EDIT (NUMBER_OF_MONITORS, DISTRIBUTION, BACKGROUND,
147.                           TOTAL_POPULATION, STANDARD_TYPE)
148.                           (COL(1), F(2), F(1), F(5), F(10), F(1));
149.  1        81       ALLOCATE AIR_QUALITY;
150.  1        82     IF (T_OPT) THEN
151.                       PUT FILE (DUMP) DATA (NUMBER_OF_MONITORS, DISTRIBUTION, BACKGROUND,
152.                           TOTAL_POPULATION, STANDARD_TYPE)          ;
153.  1        84       IF (STANDARD_TYPE = 1) THEN
154.                           DAILY_STANDARD = '1'B;
155.  1        86           ELSE
156.                           DAILY_STANDARD = '0'B;
157.  1        87       GET EDIT (POPULATION) (12(COL(1), X(4), F(10)));
158.  1        88       IF (T_OPT ! O_OPT) THEN
159.                           PUT FILE (DUMP) DATA (POPULATION);
160.  1        90       GET EDIT (NUMBER_OF_CONCENTRATIONS)
161.                           (COL(1), F(2));
162.  1        91       DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
163.  1  1     92           GET EDIT (CONCENTRATIONS(CONCENTRATION_SUB))
164.                               (COL(1), F(10));
165.  1  1     93           END;
166.  1        94     IF (T_OPT) THEN
167.                       PUT FILE (DUMP) SKIP(2);
168.  1        96     IF (T_OPT) THEN
169.                       PUT FILE (DUMP) DATA (NUMBER_OF_CONCENTRATIONS, CONCENTRATIONS);
170.  1        98       DO MONITOR = 1 TO NUMBER_OF_MONITORS;
171.  1  1     99       GET EDIT (CITY_NAME,
172.                           CITY_NUMBER(1), SITE_NUMBER(1), HOUR_TYPE(1), CARD_NUMBER(1),
173.                           (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
174.                           DO HOUR = 1 TO 6),
175.                           CITY_NUMBER(2), SITE_NUMBER(2), HOUR_TYPE(2), CARD_NUMBER(2),
176.                           (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
177.                           DO HOUR = 7 TO 13),
178.                           CITY_NUMBER(3), SITE_NUMBER(3), HOUR_TYPE(3), CARD_NUMBER(3),
179.                           (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
180.                           DO HOUR = 14 TO 20),
181.                           CITY_NUMBER(4), SITE_NUMBER(4), HOUR_TYPE(4), CARD_NUMBER(4),
182.                           (AIR_QUALITY(MONITOR, HOUR, 2), AIR_QUALITY(MONITOR, HOUR, 1)
183.                           DO HOUR = 21 TO 24, 169),
184.                           CORRECTION_1(MONITOR), CORRECTION_2(MONITOR))
185.                           (COL(1), A(11), F(2), F(3), F(2), F(2), 12(F(5)),
186.                           3(COL(1), F(3), F(3), F(2), F(2), 14(F(5))));
187.  1  1   100       IF (T_OPT) THEN
188.                           PUT FILE (DUMP) PAGE;
189.  1  1   102       IF (T_OPT) THEN
190.                           PUT FILE (DUMP) DATA  (CITY_NAME, CITY_NUMBER, SITE_NUMBER,
191.                               CARD_NUMBER, HOUR_TYPE);
192.  1  1   104           DO HOUR = 1 TO 24;
```

```
193.  1  2  105          AIR_QUALITY(MONITOR, HOUR, 1) = AIR_QUALITY(MONITOR, HOUR, 1)
194.                        * CORRECTION_1(MONITOR);
195.  1  2  106          AIR_QUALITY(MONITOR, HOUR, 2) = AIR_QUALITY(MONITOR, HOUR, 2)
196.                        * CORRECTION_2(MONITOR);
197.  1  2  107          DO J = 24, 48, 72, 96, 120, 144;
198.  1  3  108             AIR_QUALITY(MONITOR, HOUR + J, 1) =
199.                           AIR_QUALITY(MONITOR, HOUR, 1);
200.  1  3  109             AIR_QUALITY(MONITOR, HOUR + J, 2) =
201.                           AIR_QUALITY(MONITOR, HOUR, 2);
202.  1  3  110             END;
203.  1  2  111          END;
204.  1  1  112       END;
205.  1        113    DO MONITOR = 1 TO NUMBER_OF_MONITORS;
206.  1  1  114       GET EDIT (CITY_NAME,
207.                     CITY_NUMBER(1), SITE_NUMBER(1), HOUR_TYPE(1), CARD_NUMBER(1),
208.                     (AIR_QUALITY(MONITOR, HOUR, 5), AIR_QUALITY(MONITOR, HOUR, 4)
209.                     DO HOUR = 1 TO 6),
210.                     CITY_NUMBER(2), SITE_NUMBER(2), HOUR_TYPE(2), CARD_NUMBER(2),
211.                     (AIR_QUALITY(MONITOR, HOUR, 5), AIR_QUALITY(MONITOR, HOUR, 4)
212.                     DO HOUR = 7 TO 13),
213.                     CITY_NUMBER(3), SITE_NUMBER(3), HOUR_TYPE(3), CARD_NUMBER(3),
214.                     (AIR_QUALITY(MONITOR, HOUR, 5), AIR_QUALITY(MONITOR, HOUR, 4)
215.                     DO HOUR = 14 TO 20),
216.                     CITY_NUMBER(4), SITE_NUMBER(4), HOUR_TYPE(4), CARD_NUMBER(4),
217.                     (AIR_QUALITY(MONITOR, HOUR, 5), AIR_QUALITY(MONITOR, HOUR, 4)
218.                     DO HOUR = 21 TO 24, 169),
219.                     CORRECTION_4(MONITOR), CORRECTION_5(MONITOR))
220.                     (COL(1), A(11), F(2), F(3), F(2), F(2), 12(F(5)),
221.                     3(COL(1), F(3), F(3), F(2), F(2), 14(F(5))));
222.  1  1  115       IF (T_OPT) THEN
223.                     PUT FILE (DUMP) PAGE;
224.  1  1  117       IF (T_OPT) THEN
225.                     PUT FILE (DUMP) DATA  (CITY_NAME, CITY_NUMBER, SITE_NUMBER,
226.                        CARD_NUMBER, HOUR_TYPE);
227.  1  1  119          AIR_QUALITY(MONITOR, 169, 5) = AIR_QUALITY(MONITOR, 169, 5) - 0.134;
228.  1  1  120          DO HOUR = 1 TO 24;
229.  1  2  121          AIR_QUALITY(MONITOR, HOUR, 4) = AIR_QUALITY(MONITOR, HOUR, 4)
230.                        * CORRECTION_4(MONITOR);
231.  1  2  122          AIR_QUALITY(MONITOR, HOUR, 5) = AIR_QUALITY(MONITOR, HOUR, 5)
232.                        * CORRECTION_5(MONITOR) - 0.134;
233.  1  2  123             DO J = 24, 48, 72, 96, 120, 144;
234.  1  3  124                AIR_QUALITY(MONITOR, HOUR + J, 4) =
235.                              AIR_QUALITY(MONITOR, HOUR, 4);
236.  1  3  125                AIR_QUALITY(MONITOR, HOUR + J, 5) =
237.                              AIR_QUALITY(MONITOR, HOUR, 5);
238.  1  3  126                END;
239.  1  2  127             END;
240.  1  1  128          END;                          /* END OF READING AIR_QUALITY DATA */
241.  1        129    DO HOUR = -6 TO 0;
242.  1  1  130          DO MONITOR = 1 TO NUMBER_OF_MONITORS;
243.  1  2  131             AIR_QUALITY(MONITOR, HOUR, 2) =
244.                           AIR_QUALITY(MONITOR, HOUR + 168, 2);
245.  1  2  132          END;
246.  1  1  133       END;
247.  1        134    DO HOUR = -6 TO 169;
248.  1  1  135          DO MONITOR = 1 TO NUMBER_OF_MONITORS;
249.  1  2  136             AIR_QUALITY(MONITOR, HOUR, 2) =
```

```
                        EXP (AIR_QUALITY(MONITOR, HOUR, 2));
                    AIR_QUALITY(MONITOR, HOUR, 5) =
                        EXP (AIR_QUALITY(MONITOR, HOUR, 5));
                    END;
                END;
            CHARACTERISTIC_VALUE = 0.0;
            DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                GET EDIT ((MONITORS(MONITOR,MICRO_ENVIRONMENT)
                    DO MICRO_ENVIRONMENT = 1 TO 6), /* 6 IS THE FRACTION POP */
                    SITES(MONITOR))
                    (COL(21), 5F(5,2), F(6,1), COL(55), A(12));
                MONITORS(MONITOR, 8) = EXP ( LOG (AIR_QUALITY(MONITOR, 169, 5))
                    + 3.686 * AIR_QUALITY(MONITOR, 169, 4));
                CHARACTERISTIC_VALUE = MAX(CHARACTERISTIC_VALUE,
                    MONITORS(MONITOR, 8));
                            /* END OF GETTING CHARACTERISTIC VALUES */
                MONITORS(MONITOR, 7) = 1.0;  /* SET FOR AS IS EXPOSURE */
                DO HOUR = -6 TO 168;
                    AIR_QUALITY(MONITOR, HOUR, 3) =
                        MONITORS(MONITOR, 7) * AIR_QUALITY(MONITOR, HOUR, 2);

                    END;
                END;
            DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                PUT PAGE EDIT ('SITE ', SITES(MONITOR), '1 - HOUR DATA',
                    '<---MON--->    ',
                    '<---TUE--->    ',
                    '<---WED--->    ',
                    '<---THU--->    ',
                    '<---FRI--->    ',
                    '<---SAT--->    ',
                    '<---SUN--->    ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'STAND  GEO     ',
                    'HOUR    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ',
                    ' DEV   MEAN    ')
                    (LINE(3), A, A, COL(40), A,
                    LINE(5), COL(10), 7A,
                    LINE(6), COL(10), 7A,
                    LINE(7), COL(1), 8A);
                PUT SKIP(2);
                DO HOUR = 1 TO 24;
                    PUT SKIP EDIT (HOUR,
                        AIR_QUALITY(MONITOR, HOUR +  0, 1),
                        AIR_QUALITY(MONITOR, HOUR +  0, 2),
                        AIR_QUALITY(MONITOR, HOUR + 24, 1),
                        AIR_QUALITY(MONITOR, HOUR + 24, 2),
```

```
                    AIR_QUALITY(MONITOR, HOUR + 48, 1),
                    AIR_QUALITY(MONITOR, HOUR + 48, 2),
                    AIR_QUALITY(MONITOR, HOUR + 72, 1),
                    AIR_QUALITY(MONITOR, HOUR + 72, 2),
                    AIR_QUALITY(MONITOR, HOUR + 96, 1),
                    AIR_QUALITY(MONITOR, HOUR + 96, 2),
                    AIR_QUALITY(MONITOR, HOUR + 120, 1),
                    AIR_QUALITY(MONITOR, HOUR + 120, 2),
                    AIR_QUALITY(MONITOR, HOUR + 144, 1),
                    AIR_QUALITY(MONITOR, HOUR + 144, 2))
                    (F(3), 7(F(8,3), F(7,3)));
                END;
            PUT SKIP(4) EDIT ('OVERALL STANDARD DEVIATION = ',
                AIR_QUALITY(MONITOR, 169, 1),
                '    OVERALL GEOMETRIC MEAN = ',
                AIR_QUALITY(MONITOR, 169, 2))
                (COL(30), 2(A, F(7,3)));
            PUT SKIP(3) EDIT (
                'CORRECTION TO THE STANDARD DEVIATIONS WAS ',
                CORRECTION_1(MONITOR),
                '                CORRECTION TO THE MEANS WAS ',
                CORRECTION_2(MONITOR))
                (COL(30), A, F(8,5), COL(30), A, F(8,5));
            PUT PAGE EDIT ('SITE ', SITES(MONITOR), '8 - HOUR DATA',
                '<---MON--->    ',
                '<---TUE--->    ',
                '<---WED--->    ',
                '<---THU--->    ',
                '<---FRI--->    ',
                '<---SAT--->    ',
                '<---SUN--->    ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'STAND  GEO     ',
                'HOUR    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ',
                ' DEV   MEAN    ')
                (LINE(3), A, A, COL(40), A,
                LINE(5), COL(10), 7A,
                LINE(6), COL(10), 7A,
                LINE(7), COL(1), 8A);
            PUT SKIP(2);
            DO HOUR = 1 TO 24;
                PUT SKIP EDIT (HOUR,
                    AIR_QUALITY(MONITOR, HOUR +  0, 4),
                    AIR_QUALITY(MONITOR, HOUR +  0, 5),
                    AIR_QUALITY(MONITOR, HOUR + 24, 4),
                    AIR_QUALITY(MONITOR, HOUR + 24, 5),
```

```
                                AIR_QUALITY(MONITOR, HOUR + 48, 4),
                                AIR_QUALITY(MONITOR, HOUR + 48, 5),
                                AIR_QUALITY(MONITOR, HOUR + 72, 4),
                                AIR_QUALITY(MONITOR, HOUR + 72, 5),
                                AIR_QUALITY(MONITOR, HOUR + 96, 4),
                                AIR_QUALITY(MONITOR, HOUR + 96, 5),
                                AIR_QUALITY(MONITOR, HOUR + 120, 4),
                                AIR_QUALITY(MONITOR, HOUR + 120, 5),
                                AIR_QUALITY(MONITOR, HOUR + 144, 4),
                                AIR_QUALITY(MONITOR, HOUR + 144, 5))
                                (F(3), 7(F(8,3), F(7,3)));
                            END;
                        PUT SKIP(4) EDIT ('OVERALL STANDARD DEVIATION = ',
                            AIR_QUALITY(MONITOR, 169, 4),
                            '    OVERALL GEOMETRIC MEAN = ',
                            AIR_QUALITY(MONITOR, 169, 5))
                            (COL(30), 2(A, F(7,3)));
                        PUT SKIP(3) EDIT (
                            'CORRECTION TO THE STANDARD DEVIATIONS WAS ',
                            CORRECTION_4(MONITOR),
                            '                    CORRECTION TO THE MEANS WAS ',
                            CORRECTION_5(MONITOR))
                            (COL(30), A, F(8,5), COL(30), A, F(8,5));
                        END;
                    GO TO OPEN_ACTIVITY_LEVELS;
NEXT_STANDARD:
                    GET EDIT (STANDARD) (COL(1), F(5));
                    PUT STRING (STANDARD_NAME) EDIT (STANDARD) (F(6,2));
                    IF (DAILY_STANDARD) THEN
                        REDUCTION_NEEDED = (CHARACTERISTIC_VALUE * 0.852 - STANDARD) /
                            (CHARACTERISTIC_VALUE * 0.852 - BACKGROUND);
                    ELSE
                        REDUCTION_NEEDED = (CHARACTERISTIC_VALUE - STANDARD) /
                            (CHARACTERISTIC_VALUE - BACKGROUND);
                    DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                        MONITORS(MONITOR, 7) = ((MONITORS(MONITOR, 8) - BACKGROUND)
                            * (1.0 - REDUCTION_NEEDED) + BACKGROUND) / MONITORS(MONITOR, 8);
                        END;                                    /* END OF SITE REDUCTIONS */
                IF (T_OPT) THEN
                    PUT FILE (DUMP) PAGE;
                IF (T_OPT) THEN
                    PUT FILE (DUMP) DATA (MONITORS, REDUCTION_NEEDED, CHARACTERISTIC_VALUE);
                    DO HOUR = -6 TO 169;
                        DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                            AIR_QUALITY(MONITOR, HOUR, 3) =
                                MONITORS(MONITOR, 7) * AIR_QUALITY(MONITOR, HOUR, 2);
                            END;
                        END;
                IF (T_OPT) THEN
                    PUT FILE (DUMP) PAGE;
                IF (T_OPT) THEN
                    PUT FILE (DUMP) DATA (AIR_QUALITY);
%PAGE;
```

```
                    OPEN_ACTIVITY_LEVELS:
                          OPEN FILE (EXPO);
                          ON ENDFILE (EXPO) GO TO WRITE_REPORT;
                          EXPOSURES = 0;
                    GET_ACTIVITY_LEVELS:
                          GET FILE (EXPO) EDIT (OCCUPATION, SMSA, DAY_OF_WEEK,
                              PERCENT_IN_GROUP_IN, SUB_GROUP, (ACTIVITY_IN(HOUR), LEVEL_IN(HOUR)
                              DO HOUR = 1 TO 24))
                              (COL(1), F(2), F(1), F(1), F(2), X(1), A(1), 24(A(2), A(1)));

                          IF (T_OPT ¬= 0_OPT) THEN
                              PUT FILE (DUMP) SKIP DATA (OCCUPATION, DAY_OF_WEEK,
                                  PERCENT_IN_GROUP_IN, POPULATION(OCCUPATION));

                          DO HOUR = 1 TO 120;
                              PERCENT_IN_GROUP(HOUR) = 0.5217857 * PERCENT_IN_GROUP_IN;
                              END;
                          DO HOUR = 1 TO 24;
                              DO MICRO_ENVIRONMENT = 1 TO 5;
                                  IF (ACTIVITY_IN(HOUR) = ACTIVITY_NAME(MICRO_ENVIRONMENT)) THEN DO
                                      ACTIVITYS(HOUR +   0) = MICRO_ENVIRONMENT;
                                      ACTIVITYS(HOUR +  24) = MICRO_ENVIRONMENT;
                                      ACTIVITYS(HOUR +  48) = MICRO_ENVIRONMENT;
                                      ACTIVITYS(HOUR +  72) = MICRO_ENVIRONMENT;
                                      ACTIVITYS(HOUR +  96) = MICRO_ENVIRONMENT;
                                      END;
                                  END;
                              DO LEVEL = 1 TO 3;
                                  IF (LEVEL_IN(HOUR) = LEVEL_NAME(LEVEL)) THEN DO;
                                      LEVELS(HOUR +   0) = LEVEL;
                                      LEVELS(HOUR +  24) = LEVEL;
                                      LEVELS(HOUR +  48) = LEVEL;
                                      LEVELS(HOUR +  72) = LEVEL;
                                      LEVELS(HOUR +  96) = LEVEL;
                                      END;
                                  END;
                              END;
                          GET FILE (EXPO) EDIT (OCCUPATION, SMSA, DAY_OF_WEEK,
                              PERCENT_IN_GROUP_IN, SUB_GROUP, (ACTIVITY_IN(HOUR), LEVEL_IN(HOUR)
                              DO HOUR = 1 TO 24))
                              (COL(1), F(2), F(1), F(1), F(2), X(1), A(1), 24(A(2), A(1)));

                          IF (T_OPT ¬= 0_OPT) THEN
                              PUT FILE (DUMP) SKIP DATA (OCCUPATION, DAY_OF_WEEK,
                                  PERCENT_IN_GROUP_IN, POPULATION(OCCUPATION));

                          DO HOUR = 121 TO 144;
                              PERCENT_IN_GROUP(HOUR) = 0.5217857 * PERCENT_IN_GROUP_IN;
                              END;
                          DO HOUR = 1 TO 24;
                              DO MICRO_ENVIRONMENT = 1 TO 5;
                                  IF (ACTIVITY_IN(HOUR) = ACTIVITY_NAME(MICRO_ENVIRONMENT)) THEN DO
                                      ACTIVITYS(HOUR + 120) = MICRO_ENVIRONMENT;
                                      END;
                                  END;
                              DO LEVEL = 1 TO 3;
                                  IF (LEVEL_IN(HOUR) = LEVEL_NAME(LEVEL)) THEN DO;
                                      LEVELS(HOUR + 120) = LEVEL;
                                      END;
                                  END;
                              END;
```

```
 474.  1      237          GET FILE (EXPO) EDIT (OCCUPATION, SMSA, DAY_OF_WEEK,
 475.                          PERCENT_IN_GROUP_IN, SUB_GROUP, (ACTIVITY_IN(HOUR), LEVEL_IN(HOUR)
 476.                          DO HOUR = 1 TO 24))
 477.                          (COL(1), F(2), F(1), F(1), F(2), X(1), A(1), 24(A(2), A(1)));
 478.  1      238          IF (T_OPT ¬ O_OPT) THEN
 479.                          PUT FILE (DUMP) SKIP DATA (OCCUPATION, DAY_OF_WEEK,
 480.                              PERCENT_IN_GROUP_IN, POPULATION(OCCUPATION));
 481.  1      240          DO HOUR = 145 TO 168;
 482.  1  1   241              PERCENT_IN_GROUP(HOUR) = 0.5217857 * PERCENT_IN_GROUP_IN;
 483.  1  1   242              END;
 484.  1      243          IF (T_OPT) THEN
 485.                          PUT FILE (DUMP) PAGE DATA (PERCENT_IN_GROUP);
 486.  1      245          DO HOUR = 1 TO 24;
 487.  1  1   246              DO MICRO_ENVIRONMENT = 1 TO 5;
 488.  1  2   247                  IF (ACTIVITY_IN(HOUR) = ACTIVITY_NAME(MICRO_ENVIRONMENT)) THEN DO
 489.                                  ACTIVITYS(HOUR + 144) = MICRO_ENVIRONMENT;
 490.  1  2   249                      END;
 491.  1  2   250                  END;
 492.  1  1   251              DO LEVEL = 1 TO 3;
 493.  1  2   252                  IF (LEVEL_IN(HOUR) = LEVEL_NAME(LEVEL)) THEN DO;
 494.  1  2   254                      LEVELS(HOUR + 144) = LEVEL;
 495.  1  2   255                      END;
 496.  1  2   256                  END;
 497.  1  1   257              END;
 498.  1      258          DO HOUR = -6 TO 0;
 499.  1  1   259              LEVELS(HOUR) = LEVELS(HOUR + 168);
 500.  1  1   260              ACTIVITYS(HOUR) = ACTIVITYS(HOUR + 168);
 501.  1  1   261-             END;
 502.  1      262          IF (T_OPT) THEN
 503.                          PUT FILE (DUMP) PAGE DATA (LEVEL_IN, LEVELS, ACTIVITY_IN,
 504.                              ACTIVITYS);
 505.  1      264  CALCULATE_EXPOSURES:
 506.                      DO MONITOR = 1 TO NUMBER_OF_MONITORS;
 507.  1  1   265              DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
 508.  1  2   266          IF (T_OPT) THEN
 509.                          PUT FILE (DUMP) PAGE DATA (MONITOR, CONCENTRATION_SUB);
 510.  1  2   268          DO HOUR = 1 TO 168;
 511.  1  3   269              GEOMETRIC_MEAN = 0;
 512.  1  3   270              DO J = HOUR - 7 TO HOUR;
 513.  1  4   271                  GEOMETRIC_MEAN = GEOMETRIC_MEAN *
 514.                                  AIR_QUALITY(MONITOR, J, 3) *
 515.                                  MONITORS(MONITOR, ACTIVITYS(J));
 516.  1  4   272                  END;
 517.  1  3   273              GEOMETRIC_MEAN = GEOMETRIC_MEAN / 8.;
 518.  1  3   274          X = (LOG(CONCENTRATIONS(CONCENTRATION_SUB))
 519.                          - LOG(GEOMETRIC_MEAN)) /AIR_QUALITY(MONITOR, HOUR, 4);
 520.  1  3   275          IF (X < 0) THEN DO;
 521.  1  3   277              NEGATIVE_X = '1'B;
 522.  1  3   278              X = - X;
 523.  1  3   279              END;
 524.  1  3   280          ELSE DO;
 525.  1  3   281              NEGATIVE_X = '0'B;
 526.  1  3   282              END;
 527.  1  3   283          T = 1.0 / (1.0 + 0.2316419 * X);
 528.  1  3   284          F = 0.3989423 * EXP(-(X * X / 2.0));
 529.  1  3   285          FRACTION_EXCEEDING =
 530.                          ((((B(5) * T + B(4)) * T + B(3)) * T + B(2)) * T + B(1)) * T * F;
```

```
531.  1  3  286          IF (NEGATIVE_X) THEN
532.
533.  1  3  288             FRACTION_EXCEEDING = 1. - FRACTION_EXCEEDING;
534.  1  3  289          GO TO FRACTION_EXCEEDING_FOUND;
535.                  FRACTION_EXCEEDING_FOUND:
536.                      IF (T_OPT) THEN
                             PUT FILE (DUMP) SKIP;
537.  1  3  291         IF (T_OPT) THEN
538.                        PUT FILE (DUMP) DATA (HOUR, FRACTION_EXCEEDING);
539.  1  3  293           DO LEVEL = LEVELS(HOUR);
540.  1  3  294           EXPOSURES(CONCENTRATION_SUB, LEVEL) = EXPOSURES(CONCENTRATION_SUB, LEVEL)
541.                          + FRACTION_EXCEEDING * POPULATION(OCCUPATION) *
542.                          PERCENT_IN_GROUP(HOUR) * MONITORS(MONITOR, 6);
543.  1  3  295               END;                              /* END OF LEVEL                */
544.  1  3  296               END;                              /* END OF HOUR                 */
545.  1  2  297               END;                              /* END OF MONITOR              */
546.  1  1  298               END;                              /* END OF CONCENTRATION_SUB    */
547.  1     299         IF (T_OPT) THEN
548.                        PUT FILE (DUMP) SKIP(2);
549.  1     301         IF (T_OPT ! O_OPT) THEN
550.                        PUT FILE (DUMP) DATA (EXPOSURES);
551.  1     303           GO TO GET_ACTIVITY_LEVELS;
552.  1     304     %PAGE;
```

```
                WRITE_REPORT:
                    PUT PAGE EDIT ('STANDARD OF ', STANDARD_NAME, ' WITH BACKGROUND OF ',
                        BACKGROUND, CITY_NAME,
                        '                  < - G A M M A    V A L U E S - >',
                        '                  INDOORS    OTHER     TRANS     TRANS          ',
                        '     FRACTION     REDUCTION   CHARACTERISTIC',
                        'S I T E    WORK     INDOORS   VEHICLE    OTHER    OUTSID',
                        'E   POPULATION      FACTOR        VALUE     ')
                        (LINE(5), COL(35), A, A, A, F(6,2), LINE(7), COL(50), A,
                        LINE(10), A, LINE(12), A, A, LINE(13), A, A);
                    PUT SKIP(2);
                    DO MONITOR = 1 TO NUMBER_OF_MONITORS;
                        PUT SKIP EDIT (SITES(MONITOR), (MONITORS(MONITOR, J) DO J = 1 TO 8))
                            (COL(1), A(12), F(8,3), 4(F(10,3)), F(12,4), F(14,8), F(13,3));
                        END;
                    PUT PAGE;
                    PUT EDIT ('PERSON HOURS OF EXPOSURE FOR A STANDARD OF ',
                        STANDARD_NAME, ' WITH BACKGROUND OF ', BACKGROUND, CITY_NAME,
            'CONCENTRATION                                          LOW          MEDIUM          HIGH',
            '   EXCEEDED              TOTAL              ACTIVITY       ACTIVITY       ACTIVITY'
                        )
                        (LINE(5), COL(8), A, A, A, F(6,2),
                        LINE(7), COL(30), A,
                        LINE(9), A, LINE(10), A);
                    PUT SKIP(2);
                    DO CONCENTRATION_SUB = 1 TO NUMBER_OF_CONCENTRATIONS;
                        TOTAL_EXPOSURE = 0.0;
                        DO LEVEL = 1 TO 3;
                            TOTAL_EXPOSURE = TOTAL_EXPOSURE
                            + EXPOSURES(CONCENTRATION_SUB, LEVEL);
                            END;                        /* END OF SUMMING EXPOSURE */
                        PUT EDIT (CONCENTRATIONS(CONCENTRATION_SUB),
                        TOTAL_EXPOSURE,
                            EXPOSURES(CONCENTRATION_SUB, 1),
                            EXPOSURES(CONCENTRATION_SUB, 2),
                            EXPOSURES(CONCENTRATION_SUB, 3))
                            (COL(1), F(9), X(5), E(15,3), X(5), 3E(15,3));
                        PUT SKIP(2);
                        END;                            /* END CONCENTRATION_SUB */
                    CLOSE FILE (EXPO);
                    PUT FILE (SUMS) EDIT (STANDARD_NAME,
                        BACKGROUND, CONCENTRATIONS, CITY_NAME, EXPOSURES)
                        (COL(1), A(6), F(10,3), COL(1),20(F(10,3)), COL(1), A(11),
                        COL(1), 60E(20,8)));
                    GO TO NEXT_STANDARD;
                FINISHED:
                    CLOSE FILE (SYSPRINT);
                    CLOSE FILE (SUMS);
                IF (T_OPT) THEN
                    CLOSE FILE (DUMP);
                    CLOSE FILE (SYSIN);
                    RETURN;
                    END;                                /* END PROGRAM */
```

C R O S S R E F E R E N C E L I S T I N G

```
ACTIVITYS            DECLARED(57) ALLOC($(2) 001451 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL
                         DIMENSION(-6:168) ALIGNED
                 SET     200   201   202   203   204   227   248   260
                USED     260   263   271
ACTIVITY_IN          DECLARED(55) ALLOC($(2) 001427 BIT 1, 18 BITS) NONVARYING CHARACTER(2) STATIC VARIABLE INTERNAL DIMENSION(1:24)
                         UNALIGNED
                 SET     191   218   237
                USED     199   226   247   263
ACTIVITY_NAME        DECLARED(59) ALLOC($(2) 002207 BIT 1, 18 BITS) NONVARYING CHARACTER(2) STATIC VARIABLE INTERNAL DIMENSION(1:5)
                         UNALIGNED INITIAL
                 SET      59
                USED     199   226   247
AIR_QUALITY          DECLARED(29) BINARY(60) FLOAT REAL CONTROLLED VARIABLE INTERNAL DIMENSION(1:NUMBER_OF_MONITORS,-6:169,1:5)
                         ALIGNED
                 SET      99    99    99    99    99    99    99    99   105   106   108   109   114   114   114   114   114   114
                         114   114   119   121   122   124   125   131   136   137   147   181
                USED      81   105   106   108   109   119   121   122   124   125   131   136   137   143   143   147   154   154
                         154   154   154   154   154   154   154   154   154   154   154   154   156   156   161   161   161   161
                         161   161   161   161   161   161   161   161   161   161   163   163   181   187   271   274
B                    DECLARED(27) ALLOC($(2) 000735 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:5)
                         ALIGNED INITIAL
                 SET      27
                USED     285   285   285   285   285
BACKGROUND           DECLARED(18) ALLOC($(2) 000614 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET      80
                USED      83   170   171   173   173   304   310   321
CALCULATE_EXPOSURES  DECLARED(264) ALLOC($(1) C12014 ) LABEL CONSTANT INTERNAL
                NOT REF
CARD_NUMBER          DECLARED(38) ALLOC($(2) 001225 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                         ALIGNED
                 SET      99    99    99    99   114   114   114   114
                USED     103   118
CHARACTERISTIC_VALUE DECLARED(17) ALLOC($(2) 000612 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     140   144
                USED     144   170   170   171   171   178
CITY_NAME            DECLARED(35) ALLOC($(2) 001212 BIT 1, 99 BITS) NONVARYING CHARACTER(11) STATIC VARIABLE INTERNAL UNALIGNED
                 SET      99   114
                USED     103   118   304   310   321
CITY_NUMBER          DECLARED(36) ALLOC($(2) 001215 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                         ALIGNED
                 SET      99    99    99    99   114   114   114   114
                USED     103   118
CONCENTRATIONS       DECLARED(23) ALLOC($(2) 000654 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                         ALIGNED
                 SET      92
                USED      97   274   317   321
CONCENTRATION_SUB    DECLARED(7) ALLOC($(2) 000C04 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET      91   265   312
                USED      92   267   274   294   294   315   317   317   317   317
CORRECTION_1         DECLARED(31) ALLOC($(2) 000752 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                         ALIGNED
                 SET      99
                USED     105   157
CORRECTION_2         DECLARED(32) ALLOC($(2) 001022 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                         ALIGNED
```

```
                SET     99
               USED    106   157
CORRECTION_4          DECLARED(33) ALLOC($(2) 001072 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                        ALIGNED
                SET    114
               USED    121   164
CORRECTION_5          DECLARED(34) ALLOC($(2) 001142 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:20)
                        ALIGNED
                SET    114
               USED    122   164
DAILY_STANDARD        DECLARED(68) ALLOC($(2) 002742 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE INTERNAL UNALIGNED
                SET     85    86
               USED    169
DAY_OF_WEEK           DECLARED(9) ALLOC($(2) 000006 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                SET    191   218   237
               USED    193   220   239
DISTRIBUTION          DECLARED(4) ALLOC($(2) 000001 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                SET     80
               USED     83
DUMP                  DECLARED(49) ALLOC($(12) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
               USED     75    83    89    95    97   101   103   116   118   176   178   185   187   193   220   239   244   263
                       267   290   292   303   302   326
EROPT                 DECLARED(51) ENTRY CONSTANT EXTERNAL
                SET     69
            NOT USED
EXP                   DECLARED(42) BUILTIN
             NOT SET
               USED    136   137   143   284
EXPO                  DECLARED(48) ALLOC($(11) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM INPUT
               USED    188   189   191   218   237   320
EXPOSURES             DECLARED(40) ALLOC($(2) 001235 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                        DIMENSION(1:20,1:3) ALIGNED
                SET    190   294
               USED    294   302   315   317   317   317   321
EXPO_8_HR             DECLARED(1) ALLOC($(1) 013460 ) ENTRY CONSTANT EXTERNAL
             NOT REF
F                     DECLARED(26) ALLOC($(2) 000727 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                SET    284
               USED    285
FINISHED              DECLARED(323) ALLOC($(1) 013775 ) LABEL CONSTANT INTERNAL
               USED     77
FRACTION_EXCEEDING    DECLARED(21) ALLOC($(2) 000650 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                SET    285   287
               USED    287   292   294
FRACTION_EXCEEDING_FOUND  DECLARED(289) ALLOC($(1) 012447 ) LABEL CONSTANT INTERNAL
               USED    288
GEOMETRIC_MEAN        DECLARED(25) ALLOC($(2) 000725 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                SET    269   271   273
               USED    271   273   274
GET_ACTIVITY_LEVELS   DECLARED(191) ALLOC($(1) 010255 ) LABEL CONSTANT INTERNAL
               USED    303
HOUR                  DECLARED(8) ALLOC($(2) 000005 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                SET     99    99    99    99   104   114   114   114   114   120   129   134   146   153   160   179   191   194
                       197   218   221   224   237   240   245   258   268
               USED     99    99    99    99    99    99    99    99   105   105   106   106   108   108   109   109   114   114
                       114   114   114   114   114   114   121   121   122   122   124   124   125   125   131   131   136   136
                       137   137   147   147   154   154   154   154   154   154   154   154   154   154   154   154   154   154
```

```
                    154   161   161   161   161   161   161   161   161   161   161   161   161   161   161   161   181   181
                    191   191   195   199   200   201   202   203   204   208   210   211   212   213   214   218   218   222
                    226   227   231   233   237   237   241   247   248   252   254   259   259   260   260   270   270   274
                    292   293   294
HOUR_169          DECLARED(30) ALLOC($(2) 000751 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                      INITIAL
          SET        30
      NOT USED
HOUR_TYPE         DECLARED(39) ALLOC($(2) 001231 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                      ALIGNED
          SET        99    99    99    99   114   114   114   114
         USED       103   118
J                 DECLARED(63) ALLOC($(2) 002735 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
          SET       107   123   270   307
         USED       108   109   124   125   271   271   307
LEVEL             DECLARED(12) ALLOC($(2) 000011 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
          SET       207   230   251   293   314
         USED       208   210   211   212   213   214   231   233   252   254   294   294   315
LEVELS            DECLARED(58) ALLOC($(2) 001730 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL
                      DIMENSION(-6:168) ALIGNED
          SET       210   211   212   213   214   233   254   259
         USED       259   263   293
LEVEL_IN          DECLARED(56) ALLOC($(2) 001443 BIT 1, 9 BITS) NONVARYING CHARACTER(1) STATIC VARIABLE INTERNAL DIMENSION(1:24)
                      UNALIGNED
          SET       191   218   237
         USED       208   231   252   263
LEVEL_NAME        DECLARED(60) ALLOC($(2) 002212 BIT 1, 9 BITS) NONVARYING CHARACTER(1) STATIC VARIABLE INTERNAL DIMENSION(1:3)
                      UNALIGNED INITIAL
          SET        60
         USED       208   231   252
LOG               DECLARED(43) BUILTIN
      NOT SET
         USED       143   274   274
LOG_NORMAL        DECLARED(6) ALLOC($(2) 000003 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED INITIAL
          SET         6
      NOT USED
MAX               DECLARED(44) BUILTIN
      NOT SET
         USED       144
MICRO_ENVIRONMENT DECLARED(11) ALLOC($(2) 000010 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
          SET       142   198   225   246
         USED       142   199   200   201   202   203   204   226   227   247   248
MONITOR           DECLARED(10) ALLOC($(2) 000007 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
          SET        98   113   130   135   141   150   172   180   264   306
         USED        99    99    99    99    99    99    99    99    99   105   105   105   106   106   106   108   108
                    109   109   114   114   114   114   114   114   114   114   114   119   119   121   121   121   122
                    122   122   124   124   125   125   131   131   136   136   137   137   142   142   143   143   144
                    145   147   147   147   151   154   154   154   154   154   154   154   154   154   154   154   154
                    154   156   156   157   157   158   161   161   161   161   161   161   161   161   161   161   161
                    161   161   163   163   164   164   173   173   173   181   181   181   267   271   271   274   294   307
                    307
MONITORS          DECLARED(13) ALLOC($(2) 000012 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL
                      DIMENSION(1:20,1:8) ALIGNED
          SET       142   143   145   173
         USED       144   147   173   173   178   181   271   294   307
NEGATIVE_X        DECLARED(28) ALLOC($(2) 000747 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE INTERNAL UNALIGNED
          SET       277   281
```

```
                USED    286
NEXT_STANDARD       DECLARED(167) ALLOC($(1) 007443 ) LABEL CONSTANT INTERNAL
                USED    322
NUMBER_OF_CONCENTRATIONS  DECLARED(24) ALLOC($(2) 000724 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     90
                USED     91    97   265   312
NUMBER_OF_MONITORS  DECLARED(3) ALLOC($(2) 000600 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     80
                USED     83    98   113   130   135   141   150   172   180   264   306    29
OCCUPATION          DECLARED(64) ALLOC($(2) 002736 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    191   218   237
                USED    193   193   220   220   239   239   294
OPEN_ACTIVITY_LEVELS  DECLARED(188) ALLOC($(1) 010163 ) LABEL CONSTANT INTERNAL
                USED    166
OPTIONS             DECLARED(52) ALLOC($(14) 000000 BIT 1, 36 BITS) NONVARYING BIT(36) STATIC VARIABLE EXTERNAL UNALIGNED
            NOT SET
                USED     70    71    69
O_OPT               DECLARED(54) ALLOC($(136) 000000 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE EXTERNAL UNALIGNED
                 SET     71
                USED     74    88   192   219   236   301
PERCENT_IN_GROUP    DECLARED(62) ALLOC($(2) 002215 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:168)
                         ALIGNED
                 SET    195   222   241
                USED    244   294
PERCENT_IN_GROUP_IN  DECLARED(61) ALLOC($(2) 002213 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    191   218   237
                USED    193   195   220   222   239   241
POPULATION          DECLARED(20) ALLOC($(2) 000620 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL DIMENSION(1:12)
                         ALIGNED
                 SET     87
                USED     89   193   220   239   294
REDUCTION_NEEDED    DECLARED(22) ALLOC($(2) 000652 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    170   171
                USED    173   178
SITES               DECLARED(14) ALLOC($(2) 000512 BIT 1, 108 BITS) NONVARYING CHARACTER(12) STATIC VARIABLE INTERNAL
                         DIMENSION(1:20) UNALIGNED
                 SET    142
                USED    151   158   307
SITE_NUMBER         DECLARED(37) ALLOC($(2) 001221 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL DIMENSION(1:4)
                         ALIGNED
                 SET     99    99    99    99   114   114   114   114
                USED    103   118
SMSA                DECLARED(65) ALLOC($(2) 002737 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    191   218   237
            NOT USED
STANDARD            DECLARED(15) ALLOC($(2) 000606 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    167
                USED    168   170   171
STANDARD_NAME       DECLARED(16) ALLOC($(2) 000610 BIT 1, 54 BITS) NONVARYING CHARACTER(6) STATIC VARIABLE INTERNAL UNALIGNED
                         INITIAL
                 SET     16   168
                USED    304   310   321
STANDARD_TYPE       DECLARED(67) ALLOC($(2) 002741 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     80
                USED     83    84
SUBSTR              DECLARED(45) BUILTIN
            NOT SET
```

```
                USED     70    71
SUB_GROUP              DECLARED(66) ALLOC($(2) 002740 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    191   218   237    .
            NOT USED
SUMS                   DECLARED(50) ALLOC($(13) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
                USED     73   321   324
SYSIN                  DECLARED(47) ALLOC($(10) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM INPUT
                USED     76    77    80    87    90    92    99   114   142   167   327
SYSPRINT               DECLARED(46) ALLOC($(9) 000004 ) FILE STATIC CONSTANT EXTERNAL ENVIRONMENT(?) STREAM OUTPUT PRINT
                USED     72   151   152   154   156   157   158   159   161   163   164   304   305   307   309   310   311   317
                        318   323
T                      DECLARED(26) ALLOC($(2) 000731 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    283
                USED    285   285   285   285   285
TOTAL_EXPOSURE         DECLARED(41) ALLOC($(2) 001425 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    313   315
                USED    315   317
TOTAL_POPULATION       DECLARED(19) ALLOC($(2) 000616 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET     80
                USED     83
T_OPT                  DECLARED(53) ALLOC($(15) 000000 BIT 1, 1 BIT) NONVARYING BIT(1) STATIC VARIABLE EXTERNAL UNALIGNED
                 SET     70
                USED     74    82    88    94    96   100   102   115   117   175   177   184   186   192   219   238   243   262
                        266   289   291   299   301   325
WIEPULL                DECLARED(5) ALLOC($(2) 000002 BIT 1, 36 BITS) BINARY(35,0) FIXED REAL STATIC VARIABLE INTERNAL ALIGNED INITIAL
                 SET      5
            NOT USED
WRITE_REPORT           DECLARED(304) ALLOC($(1) 012654 ) LABEL CONSTANT INTERNAL
                USED    189
X                      DECLARED(26) ALLOC($(2) 000733 BIT 1, 72 BITS) BINARY(60) FLOAT REAL STATIC VARIABLE INTERNAL ALIGNED
                 SET    274   278
                USED    275   278   283   284   284

**** NO ERRORS OR WARNINGS IN ABOVE PROGRAM
END PL1 6642 IBANK 2708 DBANK
 08:54:17   PL1
 DRUM 00:00:10.393 DISC 00:00:04.188 TAPE 00:00:00.000 I/O  00:00:14.581
 CCFR 00:00:09.706 CAU  00:00:09.136 MEMY 00:00:05.814-0025K
```

```
@ELT,L        $MAP.EXPO-8              . LIST THE MAP INSTRUCTIONS
ELT007 SL73R1 11/02/79 08:54:17 (44.)
000001      040    IN EXPO-8

END ELT.
 08:54:17   ELT
 DRUM 00:00:00.029 DISC 00:00:00.261 TAPE 00:00:00.000 I/O  00:00:00.290
 CCFR 00:00:00.500 CAU  00:00:00.000 MEMY 00:00:00.039-0007K
```

REFERENCES

1. James L. Repace, Wayne R. Ott and Lance A. Wallace, "Total Human Exposure to Air Pollution," Proceedings of the 73rd Annual Meeting of the Air Pollution Control Association, Pages 80-61.6, June 1980.

2. Wayne R. Ott, "An Urban Survey Technique for Measuring the Spatial Variation of Carbon Monoxide Concentrations in Cities," Ph.D. Dissertation, Department of Civil Engineering, Stanford University, 1971.

3. Wayne R. Ott, "Development of Activity Pattern Models for Human Exposure Monitoring," EPA Office of Research and Development, Washington, D.C. Innovative Research Program Proposal, Approved July, 1 [illegible]79.

4. Yuji Horie and Jack Morrison, "Technical Memorandum on Spatial Interpolation of Air Quality Monitoring," Technology Services Corporation, Santa Monica, California, December 21, 1977.

5. Modore S. Phadke, Michael R. Grupe and George C. Tiao, "Statistical Evaluation of Trends in Ambient Concentrations of Nitric Oxide in Los Angeles," Environmental Science and Technology, Vol. 12, No. 4, pp. 430-435, April, 1978.

6. Joel Horowitz and Somir Barakat, "Statistical Analysis of the Maximum Concentration and Non-stationarity," Atmospheric Environment, Vol. 13, No. 6, pp. 811-818, (1979).

7. Yuji Horie and J. Trijonis, "Population Exposure to Oxidants and Nitrogen Dioxide in Los Angeles, Vol. VI: Analysis and Interpretation of Trends," Technology Service Corporation Report for U.S. EPA, EPA-450/3-77/004d, June, 1977.

8. Edwards C. Reifenstein, III, Robert J. Horn, III, Michael J. Keefee, "The Hackensack Meadowlands Air Pollution Study - Task 5 Report: The AQUIP Software System User's Manual," Environmental Research and Technology, Inc. ERT Document No. P-244-5, June, 1974.

9. "OAQPS Guidline Series - Guidline on Air Quality Models." U.S. EPA, EPA-450/2-78-027 and OAQPS No. 1.2-080, April, 1978.

10. S.R. Hayes," Performance Measures and Standards for Air Quality Models," U.S. EPA, EPA-450/4-79-032, October, 1979.

11. Thomas B. Feagans and William F. Biller, "A Method of Assessing the Health Risks Associated with Alternative Air Quality Standards," Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC 27711, (In preparation).

References (continued)

12. Marc F. Roddin, Hazel T. Ellis and Waheed M. Siddiqee, "Background Data for Human Activity Patterns," Vols. 1 and 2. Draft final report prepared for Strategies and Air Standards Division, Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC 27711, August, 1979.

13. Robert L. Winkler and William L. Hayes: Statistics, 2nd Edition, Holt, Rinehart and Winston, New York, 1975.

14. K.B. Schnelle, F.G. Ziegler and P.A. Krenkel, "A Study of the Vertical Distribution of Carbon Monoxide and Temperature Above an Urban Intersection," Proceedings of the 62nd Annual Air Pollution Control Association Meeting, Paper No. 69-152, 1969.

15. Anthony D. Cortese, "Ability of Fixed Monitoring Stations to Represent Personal Carbon Monoxide Exposure," Ph.D. Dissertation, Harvard School of Public Health, April, 1976.

16. Wayne R. Ott and R. Eliasson, "A Survey Technique for Determining the Representation of Urban Air Monitoring Stations with Respect to Carbon Monoxide," Journal of the Air Pollution Control Association Vol. 23, No. 8, 1973.

17. J.M. Colucci and C.R. Begemon, "Carbon Monoxide in Detroit, New York, and Los Angeles Air," Environmental Science and Technology, Vol. 3, No.1, 1969.

18. Beth C. Kleiner and John D. Spengler, "Carbon Monoxide Exposures of Boston Bicyclists," Journal of the Air Pollution Control Association, Vol. 26, No. 2 pp. 147-149, February, 1976.

19. Cesar Maldonado and Jerry A. Bullin, "Modeling Carbon Monoxide Dispersion from Roadways," Environmental Science and Technology, Vol. 11, No. 12, pp. 1071-1076, November 1977.

20. S.J. Bellamo and E. Edgerly, "Ways to Reduce Air Pollution Through Planning, Design and Operation Highways," Highway Research Board Record 356, 1971.